# AP238 Extension for Drill and Fill

This document describes the ARM/AIM mappings for an AP238 extension for the automation of processes that drill holes into assemblies and fill them with fasteners.   These operations are expected to be executed by robotic arm(s) with specialized end effectors.

The Application Objects can be divided into three groups. The first group defines digital twins for the drill and fill holes on an air frame (Sections 1.1 to 1.11). The second group defines planning information for the twins (Sections 1.12 to 1.21). The third group defines drill and fill operations (Sections 1.22 to 1.45).
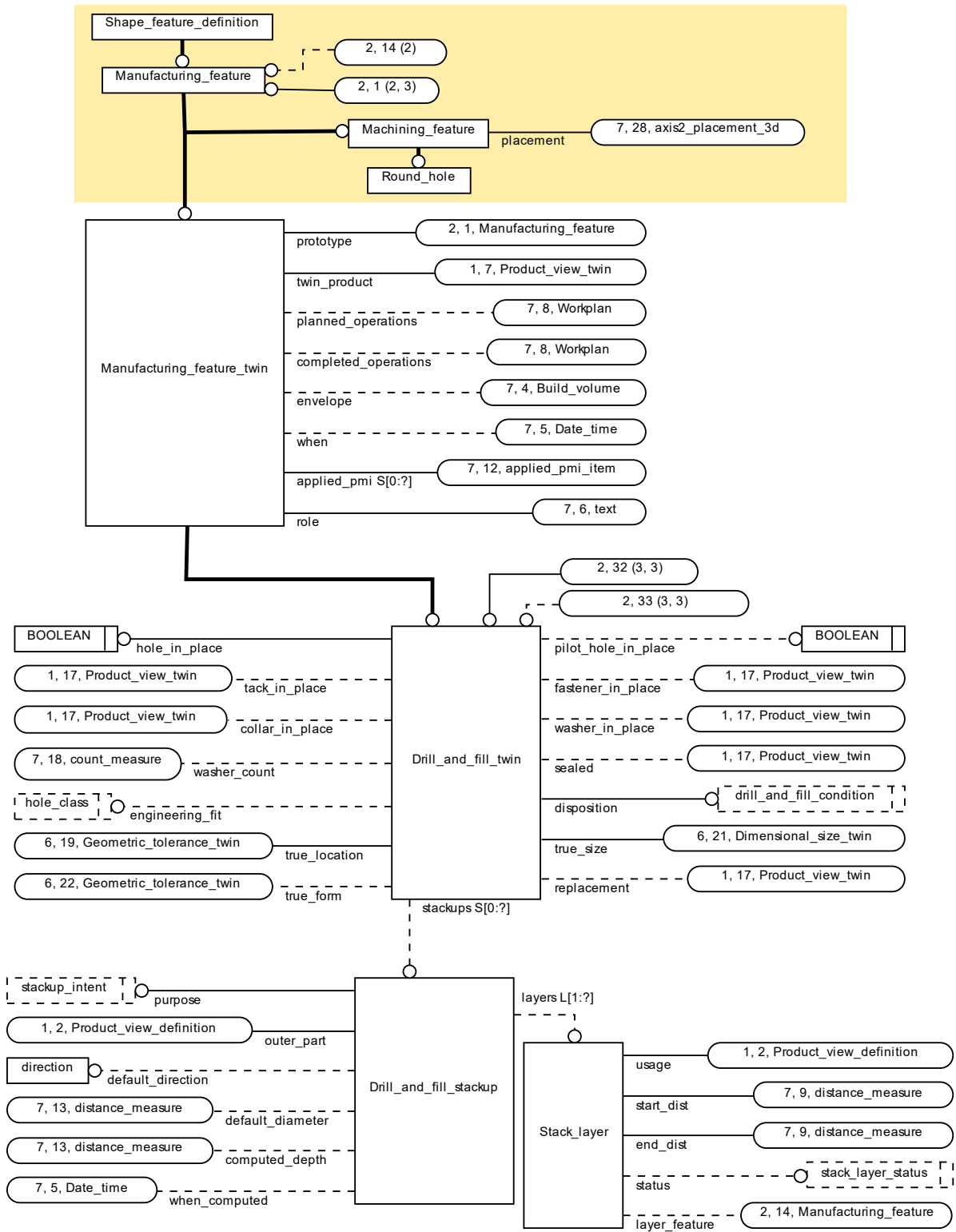
1 Application Objects

1.1 Manufacturing_feature_twin

The Manufacturing_feature_twin application object is a type of Manufacturing_feature that describes a digital twin of a feature.

```
ENTITY Manufacturing_feature_twin
SUBTYPE OF (Manufacturing_feature);
  prototype: Manufacturing_feature;
  twin_product:  Product_view_twin;
  planned_operations: OPTIONAL Workplan;
  completed_operations: OPTIONAL Workplan;
  envelope:  OPTIONAL Build_volume;
  when: OPTIONAL date_time;
  applied_pmi: SET [0:?] OF applied_pmi_item;
  role: text;
END_ENTITY;

TYPE applied_pmi_item = SELECT (Geometric_tolerance, Geometric_dimension); END_TYPE;
```

1.1.1 prototype

The as-designed state of the feature twin.

Note: In many cases the prototype is a feature described in AP242.

1.1.2 twin_product

The product that contains this digital twin feature.

1.1.3 planned_operations

The operations planned for the digital twin feature.

1.1.4 completed_operations

The operations that have been applied to the digital twin feature.

1.1.5 envelope

A volume on the product containing the digital twin prototype. If two instances of the prototype are in the envelope, then the twin shall be the instance that has the greatest volume in the envelope.

1.1.6 when

The date and time when the twin had this status. If null then the twin describes the current status.

1.1.7 applied_pmi

The pmi that has been measured on the digital twin.

1.1.8 role

The role of the twin on the product, for example, a round hole digital twin may describe a pilot hole, a tack hole, or a fastener hole.

1.2 Drill_and_fill_twin

The Drill_and_fill_twin application object is a Manufacturing_feature_twin that describes how a stack of materials is being fastened.

```
ENTITY Drill_and_fill_twin
SUBTYPE OF (Manufacturing_feature_twin);
  stackups           : OPTIONAL SET [0:?] OF Drill_and_fill_stack_up;
  hole_in_place           : BOOLEAN;   -- in-place means is on the structure
  pilot_hole_in_place     : OPTIONAL BOOLEAN;
  tack_in_place      : OPTIONAL (*AGGREGATION*) Product_view_twin;
  fastener_in_place  : OPTIONAL (*AGGREGATION*) Product_view_twin;
  collar_in_place    : OPTIONAL (*AGGREGATION*) Product_view_twin;
  washer_in_place    : OPTIONAL (*AGGREGATION*) Product_view_twin;
  washer_count       : OPTIONAL count_measure;
  sealed             : OPTIONAL (*AGGREGATION*) Product_view_twin;
  engineering_fit    : OPTIONAL hole_class;
  disposition        : drill_and_fill_condition;
  true_location      : (*COMPOSITION*) geometric_tolerance_twin;
  true_size          : (*COMPOSITION*) dimensional_size_twin;
  true_form          : OPTIONAL (*COMPOSITION*) geometric_tolerance_twin;
  replacement        : OPTIONAL Drill_and_fill_twin;
WHERE
WR1: true_location.prototype ISA position_tolerance;
WR2: true_size.prototype ISA diameter_size_tolerance;
WR3: true_form.prototype ISA roundess_tolerance OR cylindricity_tolerance
END_ENTITY;

TYPE hole_class = ENUMERATION OF (loose_running, free_running, close_running,
sliding, location); END_TYPE;

TYPE drill_and_fill_condition = ENUMERATION OF (pending, active, exception, hold,
completed, replaced); END_TYPE;
```

1.2.1 stackups

The stack of material layers in the feature. Different stackups can be measured for different stages of the process, for example, as-designed, as-assembled, and as_clamped.

1.2.2 hole_in_place

True if the fastener hole has been drilled.

1.2.3 pilot_hole_in_place

True if the pilot hole has been drilled.

1.2.4 tack_in_place

True if there is a tack in the hole.

1.2.5 fastener_in_place

The twin model of the fastener that has been placed into the hole.

1.2.6 collar_in_place

The twin model of the collar (or nut) that has been placed on the fastener.

1.2.7 washer_in_place

The twin model of the washers that have been placed on the fastener.

1.2.8 washer_count

The number of washers placed between the fastener and the material.

1.2.9 sealed

The twin model of the sealant.

1.2.10 class

If the hole is a tight fit then force will be necessary to insert the fastener. If the hole is a loose fit then the fastener will drop into place.

1.2.11 disposition

The current status of the twin

- pending if no work has been performed
- active if work is currently being performed
- completed if all the planned work has been completed
- rejection_tag if there is an issue that awaits resolution
- replaced if repeated, for example with a bigger hole and fastener

1.2.12 true_location

The as_measured location of the physical twin.

1.2.13 true_size

The as_measured size of the physical twin.

1.2.14 true_form

The as_measured form (roundness or sylindricity) of the physical twin.

1.2.15 replacement

The digital replacement if the physical twin had to replaced because of a manufacturing issue. For example, if the fastener did not fit beause of tolerance issues, then the hole may have been replaced by one with a larger diameter.

1.3   Drill_and_fill_stackup

The Drill_and_fill_Stackup application object describes the material layers in a feature.

```
ENTITY Drill_and_fill_Stackup;
  purpose           : stackup_intent;
  outer_part        : Product_view_definition;
  default_direction : OPTIONAL direction;
  default_diameter  : OPTIONAL distance_measure;
  layers            : OPTIONAL LIST [1:?] OF stack_layer;
  computed_depth    : OPTIONAL distance_measure;
  when_computed     : OPTIONAL date_time;
END_ENTITY;

TYPE stackup_intent = ENUMERATION OF (as_designed, as_assembled, as_predicted,
as_measured) END_TYPE;
```

1.3.1 purpose

The reason for this measurement of the stackup

- as-designed: the stackup as measured in a CAD system
- as-assembled: the stackup as measured with as-built shims dimensions
- as-tested: the stackup as measured with as-built dimensions for all components
- as-clamped: the stackup as measured on the assembled airframe after clamping
- as-fastened: the stackup as measured on the assembled airframe after fastening

1.3.2 outer_part

The part in the assembly where the drilling begins.

Boeing and LM have origin at bottom of skin

1.3.3 default_direction

The direction of the material removal if no feature path is given.

1.3.4 default_diameter

The diameter of the material removal if no feature profile is given.

1.3.5 layers

The list of layer depths in the stackup.

1.3.6 computed_depth

The computed depth of the stackup.

Note: The computed_depth may be the sum of the depths of the layers, or it may be the result of inspection after the fastener has been clamped.

1.3.7 when_computed

The date and time when the measurement was computed.

1.4 Stack_layer

The Stack_layer application object describes the starting and ending distance from the origin of the feature for a path through each layer of the assembly.

```
ENTITY stack_layer;
  usage             : Product_view_definition;
  start_dist        : distance_measure;
  end_dist          : distance_measure;
  status            : OPTIONAL stack_layer_status;
  layer_feature     : OPTIONAL Manufacturing_feature;
END_ENTITY;

TYPE stack_layer_status = ENUMERATION OF (air_gap, overlap); END_TYPE;
```

1.4.1 usage

The product that defines this layer of the stackup.

NOTE: A different material may be defined at each layer.

1.4.2 start_dist

The distance on the feature path from the origin to the start of this layer.

1.4.3 end_dist

The distance on the feature path from the origin to the end of this layer.

1.4.4 status

Set when there is an air gap, or overlap, between this layer and the preceding layer

NOTE An overlap indicates that some volume of each material is inside the other

1.4.5 layer_feature

An optional description of the volume removed on this layer, for example, for a drill hole a round hole may be described for the volume removed on each layer.
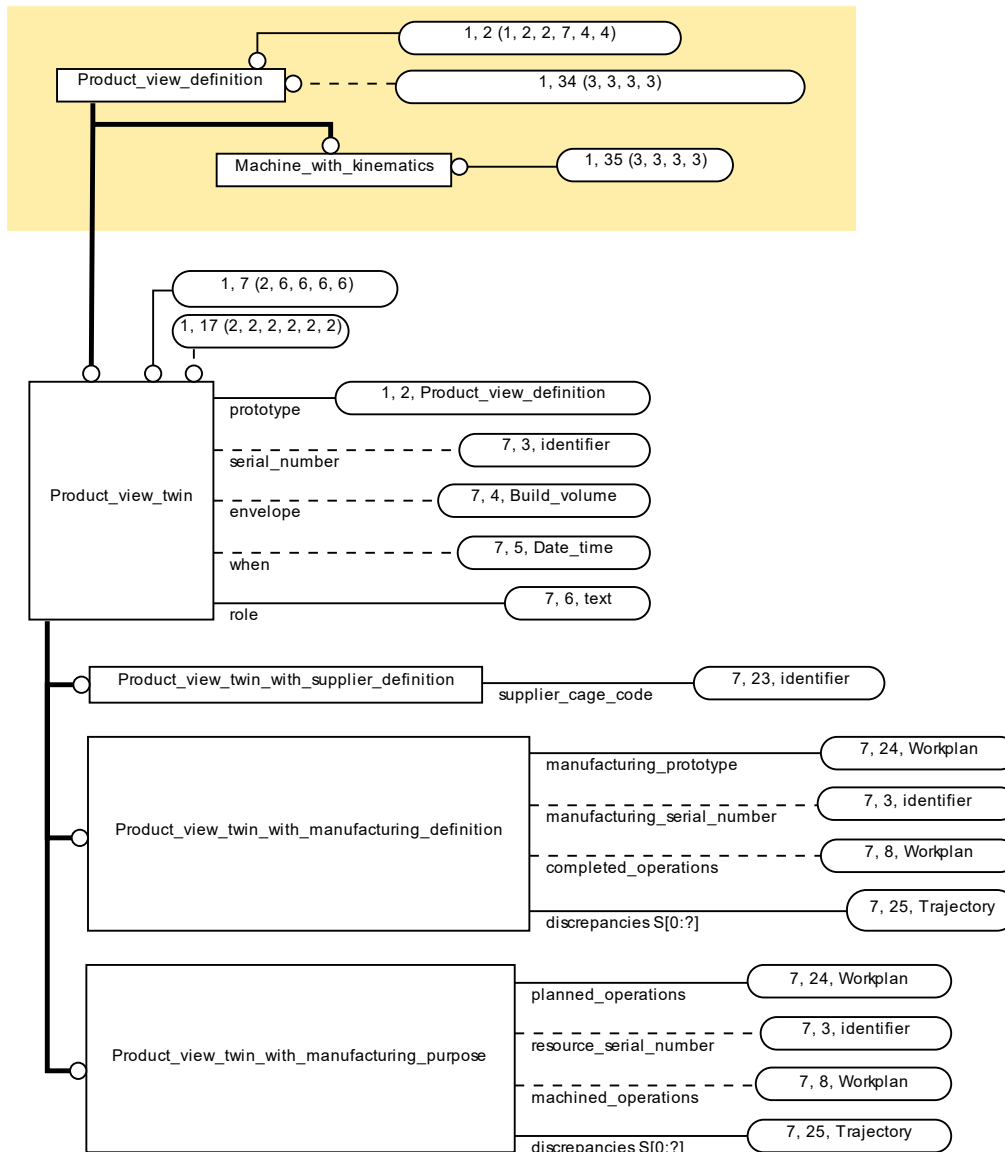
Product Twin Definitions

1.5 Product_view_twin

The product_view_twin application object is a digital twin describing as-built data for a product. If there are many digital instances of the product, for example many fasteners on a structure, then each is distinguished from the others by a serial number and/or an envelope.

```
(*IDENTIFIED*) ENTITY Product_view_twin
  SUBTYPE OF (Product_view_definition);
  prototype: Product_view_definition;
  serial_number: OPTIONAL identifier;
  envelope:  OPTIONAL Build_volume;
  when: OPTIONAL date_time;
```

```
   role: OPTIONAL text;
END_ENTITY;
```

1.5.1 prototype

The as-designed data of the product twin.

1.5.2 serial_number

An identifier that is unique to this digital twin instance with respect to the product prototype.

1.5.3 envelope

The envelope is a volume containing a prototype of the digital twin. If two instances of the prototype are in the envelope, then the twin shall be the instance that has the greatest volume in the envelope.

1.5.4 when

The date and time when the twin had this status. If null then the twin describes the current state.

1.5.5 role

The role of the twin on the product, for example, a fastener digital twin may describe a pin, a collar, a nut or a washer.

1.6 Product_view_twin_with_supplier_definition

The Product_view_twin_with_supplier_definition application object describes a digital twin made by a supplier. For example, a fastener designed by a supplier that has been substituted for the as-designed fastener.

```
(*IDENTIFIED*) ENTITY Product_view_twin_with_supplier_definition
  SUBTYPE OF (Product_view_twin);
  Supplier_cage_code:  identifier;
END_ENTITY;
```

1.6.1 Supplier_cage_code

The unique identifier of this supplier.

1.7   Product_view_twin_with_manufacturing_definition

The Product_view_twin_with_manufacturing_definition application object describes a digital twin that has been manufactured. For example, a piece part that has been machined to have a required set of features.

```
(*IDENTIFIED*) ENTITY Product_view_twin_with_manufacturing_definition
  SUBTYPE OF (Product_view_twin);
  Manufacturing_prototype : Workplan;
  Manufacturing_serial_number : OPTIONAL identifier;
  completed_operations : OPTIONAL Workplan;
  discrepancies: SET OF Trajectory;
END_ENTITY;
```

1.7.1   manufacturing_protoype

The planned workplan for making this product.

1.7.2   manufacturing_serial_number

A unique identifier defined by production for this instance of its manufacturing.

1.7.3   completed operations

The manufacturing operations completed on the digital twin.

1.7.4   discrepancies

A set of tool path trajectories in the completed operations in which one or more process parameters were out of bounds.

1.8   Product_view_twin_with_manufacturing_purpose

The Product_view_twin_with_manufacturing_purpose application object describes a digital twin of a product that is used as a cutter, fixture or other manufacturing resource.

```
ENTITY Product_view_twin_with_manufacturing_purpose
  SUBTYPE OF (Product_view_twin);
  planned_operations: Workplan;
  resource_serial_number: OPTIONAL identifier;
  machined_operations: OPTIONAL Workplan;
  discrepancies: SET OF Trajectory;
END_ENTITY;
```

1.8.1 planned_operations

The operations that will use this product as a resource. For example, as a fixture or as a cutter.
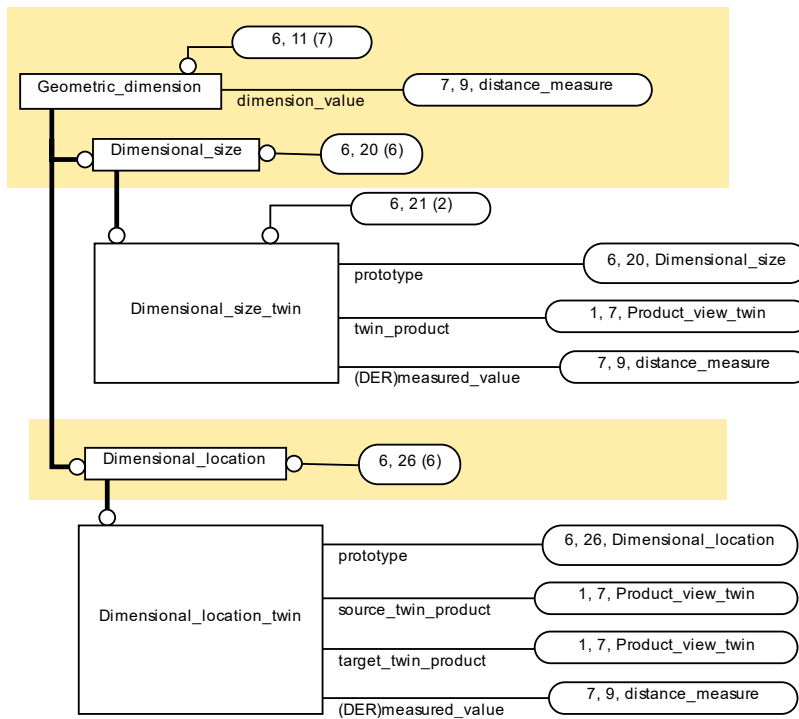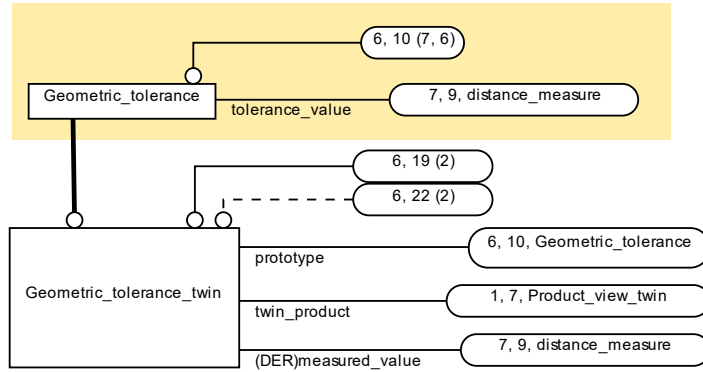
1.8.2 resource_serial_number

A unique identifier for this instance of the resource.

1.8.3 machined_operations

The completed manufacturing operations that used this resource.

1.8.4 discrepancies

A set of tool path trajectories in the completed operations in which one or more process parameters were out of bounds.

Tolerance Twin Definitions

1.9 Geometric_tolerance_twin

The Geometric_tolerance_twin application object describes an as-measured tolerance for a digital twin.

```
ENTITY Geometric_tolerance_twin
  SUBTYPE OF (Geometric_tolerance);
  prototype: Geometric_tolerance;
  twin_product:  Product_view_twin;
DERIVE
  measured_value : distance_measure :=
      SELF\Geometric_tolerance.tolerance_value;
```

```
END_ENTITY;
```

1.9.1 prototype

The as-designed value of the tolerance.

1.9.2 twin_product

The digital twin for which the tolerance has been measured.

NOTE: The prototype of the twin_product must contain the prototype of the tolerance.

1.9.3 measured_value

The as_measured value of the tolerance on the digital twin.

1.10 Dimensional_size_twin

The Dimensional_size_twin application object describes an as-measured size dimension for a digital twin.

```
ENTITY Dimensional_size_twin
  SUBTYPE OF (Dimensional_size);
  prototype: Dimensional_size;
  twin_product:  Product_view_twin;
DERIVE
  measured_value : distance_measure :=
     SELF\Geometric_dimension.dimension_value;
END_ENTITY;
```

1.10.1 prototype

The as-designed value of the dimension.

1.10.2 twin_product

The digital twin for which the dimension has been measured.

NOTE: The prototype of the twin_product must contain the prototype of the dimension.

1.10.3 measured_value

The as_measured value of the dimension on the digital twin.

1.11 Dimensional_location_twin

The Dimensional_location_twin application object describes an as-measured location dimension for a digital twin.

```
ENTITY Dimensional_location_twin
  SUBTYPE OF (Dimensional_location);
  prototype: Dimensional_location;
  source_twin_product:  Product_view_twin;
  target_twin_product:  Product_view_twin;
DERIVE
  measured_value : distance_measure :=
      SELF\Geometric_dimension.dimension_value;
END_ENTITY;
```

1.11.1 prototype

The as-designed value of the dimension.

1.11.2 source_twin_product

The digital twin for which the source of the dimension has been measured.

NOTE: The prototype of the Source_twin_product must contain the prototype of the source of the dimension.
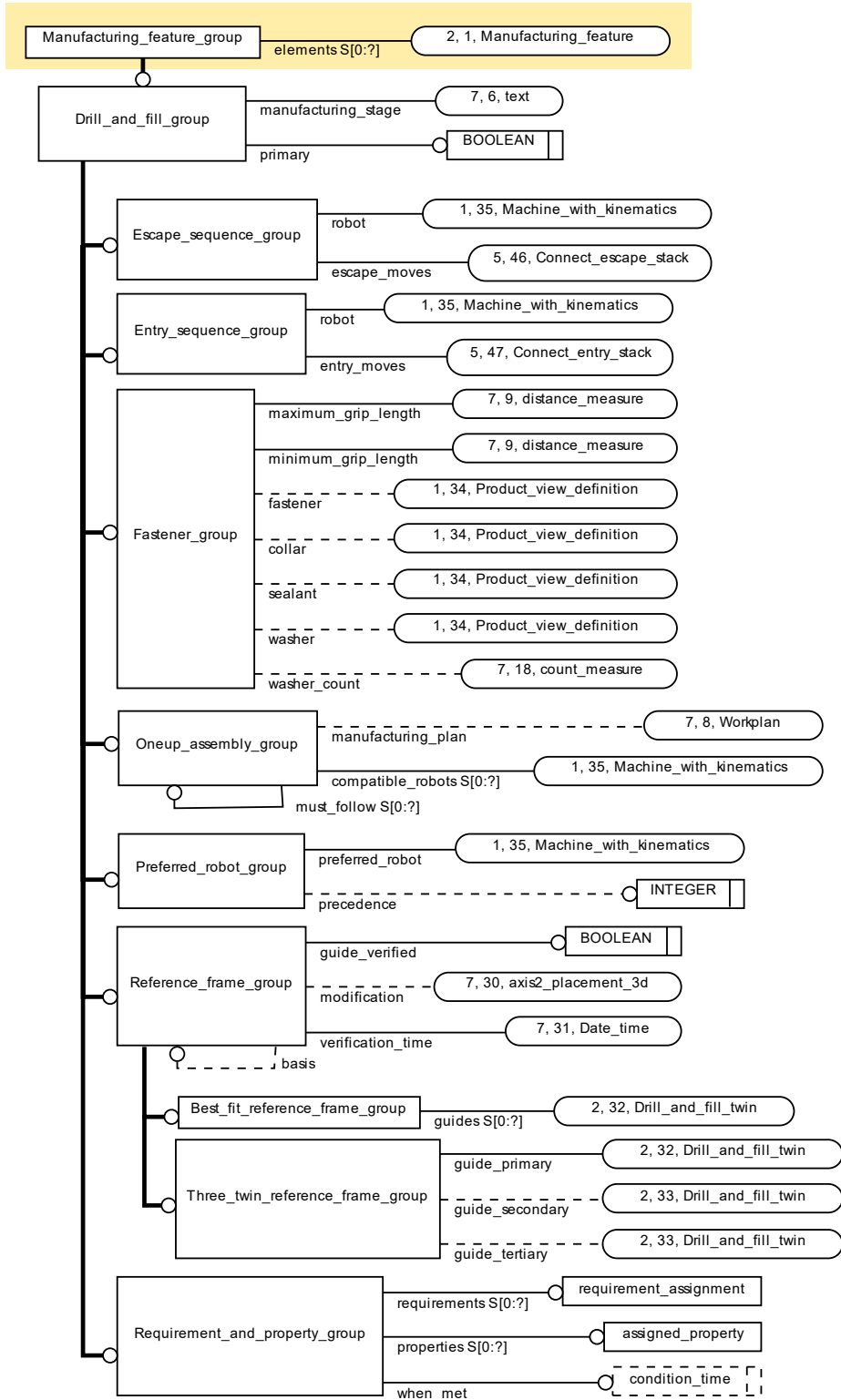
1.11.3 target_twin_product

The digital twin for which the target of the dimension has been measured.

NOTE: The prototype of the Target_twin_product must contain the prototype of the target of the dimension.

1.11.4 measured_value

The as_measured value of the dimension on the digital twin.

Drill and Fill Group Definitions

1.12 Drill_and_fill_group

The Drill_and_fill_group application object describes planning information for a group of drill and fill holes.

```
ENTITY Drill_and_fill_group
ABSTRACT SUPERTYPE
SUBTYPE OF (Manufacturing_feature_group);
  manufacturing_stage     : text;      -- phase 1, phase 2 etc.
  primary : BOOLEAN;
END_ENTITY;
```

1.12.1 manufacturing_phase

The manufacturing phase when this group contains relevant planning information. For example, a manufacturing plan may be divided into phases called "Phase 1", "Phase 2" and "Phase 3".

1.12.2 primary

This grouping defines a primary property for this set of features. For example, the primary or preferred fastener for this hole.

1.13 Reference_frame_group

The Reference_frame_group application object describes a reference frame that can be used to correct the location and axis orientation of a group of holes.

```
ENTITY Reference_frame_group
SUBTYPE OF (Drill_and_fill_group);
  guide_verified    : BOOLEAN; -- have the guides been checked
  basis                  : OPTIONAL Reference_frame_group;
  modification           : OPTIONAL axis2_placement_3d;   -- transform computed from
guides
  verification_time : Date_time; -- because stale after 12 hours
END_ENTITY;
```

1.13.1 guide_verified

The guide_verified is set to true when the guide has been checked.

1.13.2 basis

The basis to be used when computing the modification for this reference frame group. If no basis is set then the global coordinate system shall be used as the base.

1.13.3 modification

The modification against the basis necessary to correctly position and orient any drilling operations generated to make holes for the members of this group.

1.13.4 verification_time

The date and time when the guides were last checked. For example, in some enterprises a guide is considered stale after 12 hours and must be computed again.

1.14 Three_twin_reference_frame_group

The Three_twin_reference_frame_group application object describes a reference frame that is computed using three guides.

```
ENTITY Three_twin_reference_frame_group
SUBTYPE OF (reference_frame_group);
  guide_primary          : Drill_and_fill_twin;
  guide_secondary  : OPTIONAL Drill_and_fill_twin;
  guide_tertiary   : OPTIONAL Drill_and_fill_twin;
END_ENTITY;
```

1.14.1 guide primary

The primary reference point for the guide. This point is required and defines the displacement required to correctly position the group.

1.14.2 guide secondary

The secondary reference point for the guide. If set this point determines the axis of the guide.

1.14.3 guide tertiary

The tertiary reference point for the guide. If set this point determines the reference axis of the guide.

1.15 Best_fit_reference_frame_group

The Best_fit_reference_frame_group application object describes a reference frame that is computed using a set of guides.

```
ENTITY Best_fit_reference_frame_group
```

```
SUBTYPE OF (Reference_frame_group);
   guides            : SET OF Drill_and_fill_twin;
END_ENTITY;
```

1.15.1 guides

The points used to compute the best fit.

1.16 Fastener_group

The Fastener_group application object describes a fastener configuration that can be used for a group of holes.

```
-- group of holes with the same suggested fastener
ENTITY Fastener_group
SUBTYPE OF (Drill_and_fill_group);
   maximum_grip_length    : distance_measure;
   minimum_grip_length    : distance_measure;
   fastener          : OPTIONAL Product_view_definition;
   collar            : OPTIONAL Product_view_definition;
   sealant           : OPTIONAL Product_view_definition;
   washer            : OPTIONAL Product_view_definition;
   washer_count      : OPTIONAL count_measure;
END_ENTITY;
```

1.16.1 maximum_grip_length

The maximum grip length allowed for the holes in this fastener group.

1.16.2 minimum_grip_length

The minimum grip length allowed for the holes in this fastener group.

1.16.3 fastener

The recommended fastener for the holes in this fastener group.

1.16.4 collar

The recommended collar for the holes in this fastener group.

1.16.5 sealant

The recommended sealant for the holes in this fastener group.

1.16.6 washer

The recommended washer for this assembly.

1.16.7 washer count

The washer count required for this fastener assembly.

1.17 Oneup_assembly_group

The Oneup_assembly_group application object describes a group of holes that need to be drilled together to meet the requirements of oneup assembly.

```
-- group of holes that are drilled together
ENTITY Oneup_assembly_group
SUBTYPE OF (Drill_and_fill_group);
  manufacturing_plan      : OPTIONAL Workplan;
  compatible_robots : SET [0:?] OF Machine_with_kinematics;
  must_follow : SET [0:?] OF Oneup_assembly_group;
END_ENTITY;
```

1.17.1 manufacturing_plan

The recommended drilling solution.

1.17.2 compatible_robots

The robots that can run the recommended solution.

1.17.3 must_follow

The set of other one-up assembly groups that must be completed before this group begins.

1.18 Preferred_robot_group

The preferred_robot_group application object describe a robot that is the preferred choice for a group of holes.

```
-- group of holes that prefer to use the same robot
```

```
ENTITY Preferred_robot_group
SUBTYPE OF (Drill_and_fill_group);
  preferred_robot  : Machine_with_kinematics;
  precedence       : OPTIONAL INTEGER;
END_ENTITY;
```

1.18.1 preferred_robot

A robot that can be selected for this group of holes.

1.18.2 precedence

A precedence level when multiple robots can be selected

1.19 Escape_sequence_group

The Escape_sequence_group application object describes a safe escape sequence for the group of holes when the programmed sequence must be interrupted.

```
-- how to pull away for unplanned changes in sequence
ENTITY Escape_sequence_group
SUBTYPE OF (Drill_and_fill_group);
  robot                 : Machine_with_kinematics;
  escape_moves          : Connect_escape_stack;
END_ENTITY;
```

1.19.1 robot

The robot that uses this escape sequence.

1.19.2 escape_moves

The stack of escape moves for the robot.

1.20 Entry_sequence_group

The Entry_sequence_group application object describes a safe entry sequence for the group of holes when a new programmed sequence is started.

```
-- how to approach for drill and fill for unplanned changes in sequence
ENTITY Entry_sequence_group
SUBTYPE OF (Drill_and_fill_group);
  robot          : Machine_with_kinematics;
  entry_moves    : Connect_entry_stack;
END_ENTITY;
```

1.20.1 robot

The robot that uses this entry sequence.

1.20.2 entry_moves

The stack of entry moves for the robot.

1.21 Requirement_and_property_group

The Requirement_and_property_group application object describes requirements and properties that must be met by the drill points in the group.

```
-- PMI constraints on this group
ENTITY Requirement_and_property_group
SUBTYPE OF (Drill_and_fill_group);
  requirements      : SET OF requirement_assignment;
  properties        : SET OF assigned_property;
  when_met          : condition_time;
END_ENTITY;

TYPE condition_time = ENUMERATION OF (pre_condition, post_condition,
pre_and_post_condition); END_TYPE;
```
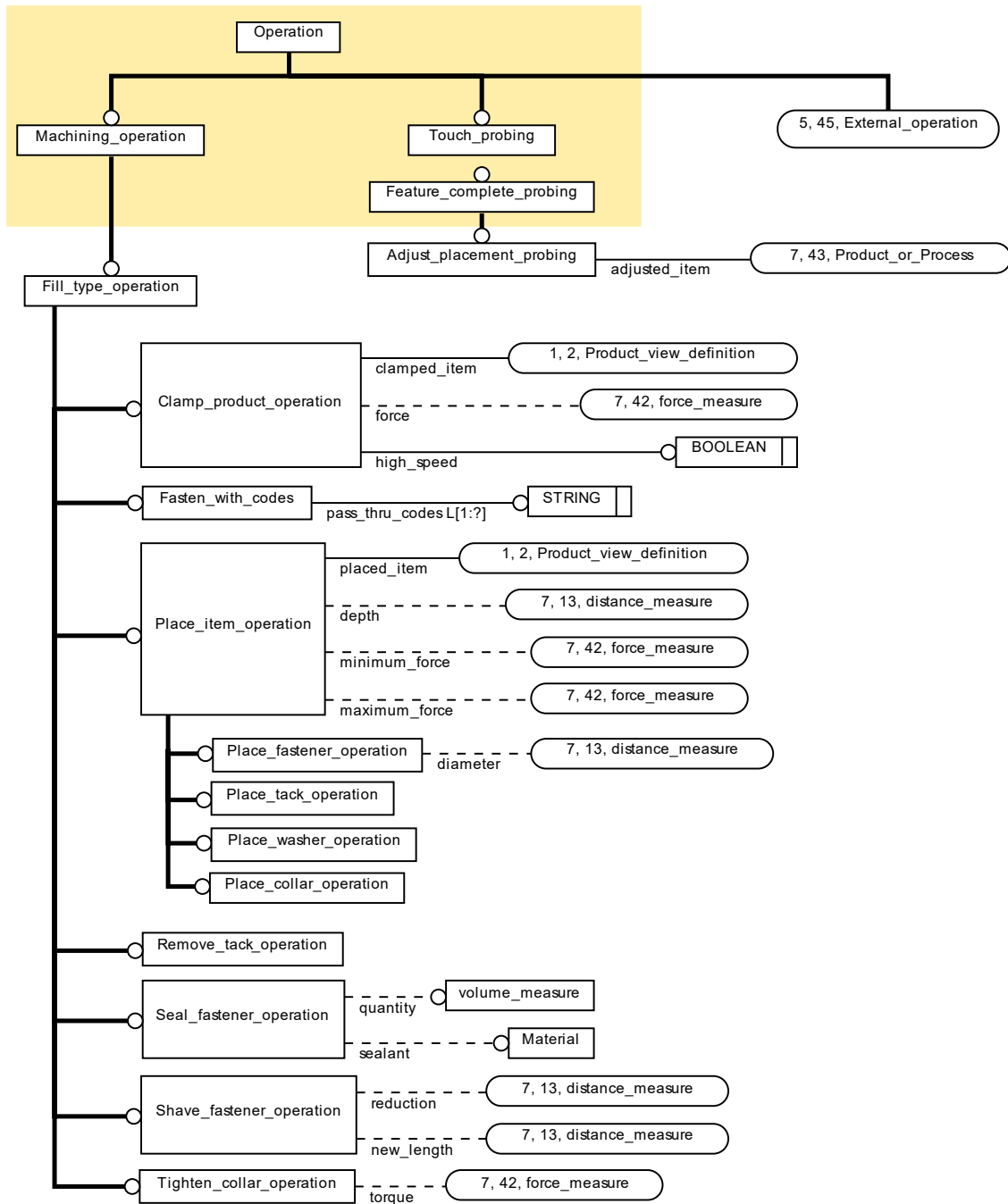
1.21.1 requirements

A set of dimensional and tolerance constraints.

1.21.2 properties

A set of properties such as material, hardness and surface condition.

1.21.3 when_met

An indication of whether these properties should be met before the operation, after the operation. or both before and after the operation.

Drill and Fill Operation Definitions

1.22 Fill_type_operation

The Fill_type_operation application object is a Machining_operation that adds a product to the as_is model.

```
ENTITY Fill_type_operation
```

```
   SUBTYPE_OF (Machining_operation);
END_ENTITY
```

1.23 Clamp_product_operation

The Clamp_product_operation application object is a Fill_type_operation that clamps a structure
during manufacturing.

```
ENTITY Clamp_product_operation
  SUBTYPE_OF (Fill_type_operation);
  clamped_item      : Product_view_definition;
  force             : OPTIONAL force_measure;
  high_speed        : BOOLEAN;
END_ENTITY;
```

1.23.1 clamped_item

The item that is to be clamped.

1.23.2 force

The force to be applied during the clamping.

1.23.3 high_speed

True if the clamping is to be done at high speed.

1.24 Fasten_with_codes

The Fasten_with_codes application object is a Fasten_operation that uses machine-specific codes
to achieve its effect.

```
ENTITY Fasten_with_codes
  SUBTYPE_OF (Fill_type_operation);
  pass_thru_codes   : LIST [1:?] OF STRING;
END_ENTITY;
```

1.24.1 pass_thru_codes

The enterprise specific codes that are to be used to control the manufacturing.

1.25 Place_item_operation

The Place_item_operation application object is a Fill_type_operation that places an item into a feature.

```
-- The as-selected fastener may be different to the as-planned
ENTITY Place_item_operation
  SUBTYPE OF (Fill_type_operation);
  placed_item       : Product_view_definition;
  depth             : OPTIONAL distance_measure;
  minimum_force     : OPTIONAL force_measure;
  maximum_force     : OPTIONAL force_measure;
END_ENTITY;
```

1.25.1 placed_item

Definition of the item to be placed into the feature. The digital twin selected shall use this definition as a prototype.

1.25.2 depth

The distance from the top of the feature, in the direction of the axis of the feature, where the item is to be placed.

1.25.3 minimum_force

The minimum force necessary to place the fastener or sequeeze a rivet into the feature.

1.25.4 maximum_force

The maximum force necessary to place the fastener or squeeze a rivet into the feature.

1.26 Place_fastener_operation

The Place_fastener_operation application object is a Fill_type_operation that places a fastener.

```
ENTITY Place_fastener_operation
  SUBTYPE OF (Place_item_operation);
  diameter          : OPTIONAL distance_measure;
END_ENTITY;
```

1.26.1 diameter

The expected diameter for the placed item.

1.27 Place_tack_operation

The Place_tack_operation application object is a Fill_type_operation that places a temporary fastener.

```
ENTITY Place_tack_operation
  SUBTYPE OF (Place_item_operation);
END_ENTITY;
```

1.28 Place_washer_operation

The Place_washer_operation application object is a Fill_type_operation that places a washer.

```
ENTITY Place_washer_operation
  SUBTYPE OF (Place_item_operation);
END_ENTITY;
```

1.29 Place_collar_operation

The Place_collar_operation application object is a Fill_type_operation that places a collar.

```
ENTITY Place_collar_operation
  SUBTYPE OF (Place_item_operation);
END_ENTITY;
```

1.30 Remove_tack_operation

The Remove_tack_operation application object removes a temporary fastener from a feature..

```
ENTITY Remove_tack_operation
  SUBTYPE OF (Fill_type_operation);
END_ENTITY;
```

1.31 Seal_fastener_operation

The Seal_fastener_operation application object is a Fill_type_operation that seals the fastener in a feature.

```
ENTITY Seal_fastener_operation
  SUBTYPE OF (Fill_type_operation);
  quantity          : OPTIONAL volume_measure;
  sealant           : OPTIONAL material;
END_ENTITY;
```

1.31.1 quantity

The volume of sealant to be applied

1.31.2 sealant

The sealant material.

1.32 Shave_fastener_operation

The Shave_fastener_operation application object is a Fill_type_operation that reduces the length of the fastener for a feature.

```
ENTITY Shave_fastener_operation
  SUBTYPE OF (Fill_type_operation);
  reduction  : OPTIONAL distance_measure;
  new_length : OPTIONAL distance_measure;
END_ENTITY;
```

1.32.1 reduction

The length of material to be removed.

1.32.2 new_length

The required length of the fastener after shaving.

1.33 Tighten_collar_operation

The Tighten_collar_operation application object is a Fill_type_operation that tightens the collar on a fastener in a feature.

```
ENTITY Tighten_collar_operation
  SUBTYPE OF (Fill_type_operation);
  torque          : OPTIONAL force_measure;
END_ENTITY;
```

1.33.1 torque

The force to be applied to tighten the collar

1.34 Adjust_placement_probing

The Adjust_placement_probing application object is a Feature_complete_probing that adjusts the position of a product, such as a fastener, or a process such as a drilling operation.

```
ENTITY Adjust_placement_probing
  SUBTYPE_OF (Feature_complete_probing);
  adjusted_item           : Product_or_Process;
END_ENTITY;

TYPE Product_or_Process = SELECT(
    Product_view_definition,
    Executable);
END_TYPE;
```

1.34.1 adjusted_item

The product or process to be adjusted.
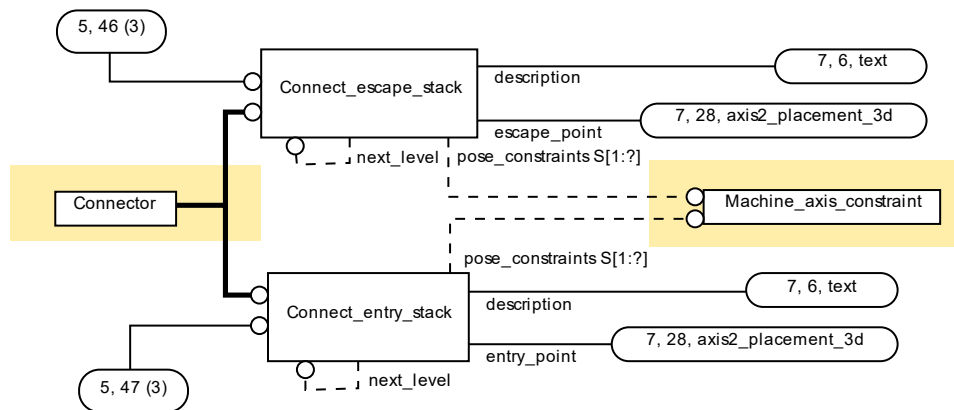
Connector Definitions

1.35 Connect_escape_stack

The Connect_escape_stack application object is a kind of Connector. It describes a safe escape when the operation sequence interrupted.

```
ENTITY Connect_escape_stack
  SUBTYPE OF (Connector);
  description      : text;
  escape_point     : axis2_placement_3d;
  pose_constraints : OPTIONAL SET [1:?] OF Machine_axis_constraint;
  next_level       : OPTIONAL Connect_escape_stack;
END_ENTITY;
```

1.35.1 description

Human readable summary of the robot configuration at this point in the escape sequence, for example elbow_up, bottom_out and neck_down. /* airframe.

1.35.2 escape_point

The required new point and orientation for the robot when it reaches this level.

1.35.3 pose_constraints

Axis constraints that must be met when the robot reaches the new point. For example, if the robot has a wide back then it may be constrained to keep the back away from the airframe.

1.35.4 next_level

Depending on the situation a robot may need to escape over multiple levels to avoid fixtures and workpieces. For example, an escape to a new location that does not need to avoid geometry should only need one level, an escape that needs to avoid a local fixture may need two levels, and an escape that needs to reach a point on the other side of the airframe may need three levels.

1.36 Connect_entry_stack

The Connect_entry_stack application object is a kind of Connector. It describes a safe entry procedure when the operation sequence is interrupted.

```
ENTITY Connect_entry_stack
  SUBTYPE OF (Connector);
  description       : text;
  entry_point       : axis2_placement_3d;
  pose_constraints  : OPTIONAL SET [1:?] OF Machine_axis_constraint;
  next_level        : OPTIONAL Connect_entry_stack;
END_ENTITY;
```

1.36.1 description

Human readable summary of the robot configuration at this point in the escape sequence, for example elbow_up, bottom_out and neck_down.

1.36.2 entry_point

The required new point and orientation for the robot when it reaches this level.

1.36.3 pose_constraints

Axis constraints that must be met when the robot reaches the new point. For example, if the robot has a wide back then it may be constrained to keep the back away from the airframe.

1.36.4 next_level

Depending on the situation a robot may need to approach over multiple levels. For example, an approach that does not need to avoid geometry should only need one level, an approach that needs to avoid a local fixture may need two levels, and an approach that needs to reach a point on the other side of the airframe may need three levels.
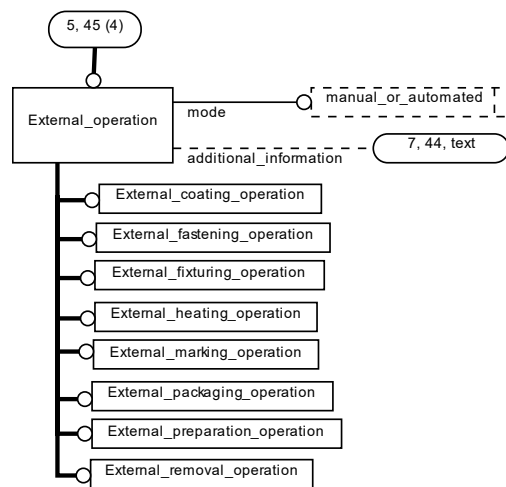
External Operation Definitions

1.37 External_operation

The External_operation application object is an operation performed by an external system that is beyond the scope of the automation defined in this project.

Note: An external_operation documents an unprogrammed operation that has been applied to a digital twin.

```
ENTITY External_operation
  SUBTYPE OF (operation);
  mode                    : manual_or_automated;
  additional_information  : OPTIONAL Text;
  applied_to              : OPTIONAL manufacturing_feature;
END_ENTITY;

TYPE manual_or_automated = ENUMERATION OF (manual, automated); END_TYPE;
```

1.37.1 mode

the external operation is manual or automated.

1.37.2 additional_information

additional information about the operation such as "cooling", or one of its subtypes such as "laser heating".

1.37.3 applied_to

the manufacturing_feature impacted by this operation.

1.38 External_heating_operation

```
ENTITY External_heating_operation
  SUBTYPE OF (External_operation);
END_ENTITY;
```

The External_heating_operation application object documents that an operation has heated the part.

1.39 External_marking_operation

```
ENTITY External_marking_operation
  SUBTYPE OF (External_operation);
END_ENTITY;
```

The External_marking_operation application object documents that an operation has marked the part.

1.40 External_coating_operation

```
ENTITY External_coating_operation
  SUBTYPE OF (External_operation);
END_ENTITY;
```

The External_coating_operation application object documents that an operation has coated the part.

1.41 External_packaging_operation

```
ENTITY External_packaging_operation
  SUBTYPE OF (External_operation);
END_ENTITY;
```

The External_packaging_operation application object documents that an operation has packaged the part.

1.42 External_fastening_operation

```
ENTITY External_fastening_operation
  SUBTYPE OF (External_operation);
END_ENTITY;
```

The External_fastening_operation application object documents that an operation has fastened the part.

1.43 External_fixturing_operation

```
ENTITY External_fixturing_operation
  SUBTYPE OF (External_operation);
END_ENTITY;
```

The External_fixturing_operation application object documents that an operation has fixtured the part.

1.44 External_preparation_operation

```
ENTITY External_preparation_operation
  SUBTYPE OF (External_operation);
END_ENTITY;
```

The External_preparation_operation application object documents that an operation has prepared the part.

1.45 External_removal_operation

```
ENTITY External_removal_operation
  SUBTYPE OF (External_operation);
END_ENTITY;
```

The External_removal_operation application object documents that an operation has removed material from the part.

Note: If desirable the before and after state of the part can be documented using as_is and to_be workpieces attached to the workingstep.

2 Features Mapping specification

2.1 MANUFACTURING_FEATURE_TWIN

```
AIM element: twin_feature
Source:      10303-238
Reference path:
twin_feature <=
instanced_feature <=
[shape_aspect]
[ feature_definition <=
characterized_object]
```


2.1.1 manufacturing_feature_twin to manufacturing_feature (as prototype)

```
AIM element: PATH
Reference path:
twin_feature <=
instanced_feature <=
shape_aspect <-
shape_aspect_relationship.relating_shape_aspect
shape_aspect_relationship =>
{shape_aspect_relationship.name ='prototype'}
shape_aspect_relationship.related_shape_aspect ->
shape_aspect =>
instanced_feature
```

2.1.2 manufacturing_feature_twin to product_view_twin (as twin_product)

```
AIM element: PATH
Reference path:
twin_feature <=
instanced_feature <=
shape_aspect
shape_aspect.of_shape ->
product_definition_shape <=
property_definition
property_definition.definition ->
characterized_definition
characterized_definition = characterized_product_definition
characterized_product_definition
characterized_product_definition = product_definition
product_definition
```

2.1.3   manufacturing_feature_twin to workplan (as planned_operations)

```
AIM element: PATH
Reference path:
twin_feature <=
instanced_feature <=
shape_aspect
action_method_items = shape_aspect
action_method_items <-
applied_action_method_assignment.items[i]
applied_action_method_assignment <=
action_method_assignment
{ action_method_assignment.role ->
action_method_role
action_method_role.name = 'planned' }
action_method_assignment.assigned_action_method ->
action_method =>
machining_process_executable =>
machining_workplan
```

2.1.4   manufacturing_feature_twin to workplan (as completed_operations)

```
AIM element: PATH
Reference path:
twin_feature <=
instanced_feature <=
shape_aspect
action_method_items = shape_aspect
action_method_items <-
applied_action_method_assignment.items[i]
applied_action_method_assignment <=
action_method_assignment
{ action_method_assignment.role ->
action_method_role
action_method_role.name = 'completed' }
action_method_assignment.assigned_action_method ->
action_method =>
machining_process_executable =>
machining_workplan
```

2.1.5   envelope

```
AIM element: shape_representation_with_parameters
Source:      10303-47
Reference path:
twin_feature <=
instanced_feature <=
shape_aspect
shape_definition = shape_aspect
shape_definition
characterized_definition = shape_definition
characterized_definition <-
```

```
property_definition.definition
{property_definition =>
product_definition_shape}
property_definition <-
represented_definition = property_definition
represented_definition <-
property_definition_representation.definition
{property_definition_representation =>
shape_definition_representation}
property_definition_representation
property_definition_representation.used_representation ->
representation =>
shape_representation =>
shape_representation_with_parameters
```

2.1.6 when

```
AIM element: date_and_time
Source:        10303-41
Reference path:
twin_feature <=
instanced_feature <=
characterized_object
date_and_time_item = characterized_object
date_and_time_item <-
applied_date_and_time_assignment.items[i]
applied_date_and_time_assignment <=
date_and_time_assignment
{ date_and_time_assignment.role ->
date_time_role
date_time_role.name = 'measured' }
date_and_time_assignment.assigned_date_and_time ->
date_and_time
```

2.1.7 applied_pmi

HOW TO ATTACH?

2.1.8 role

```
AIM element: descriptive_representation_item.description
Source:        10303-45
Reference path:
twin_feature <=
instanced_feature <=
shape_aspect
shape_definition = shape_aspect
shape_definition
characterized_definition = shape_definition
characterized_definition <-
property_definition.definition
property_definition
```

```
{property_definition.name = 'role'}
represented_definition = property_definition
represented_definition <-
property_definition_representation.definition
property_definition_representation
property_definition_representation.used_representation ->
representation
representation.items[i] ->
representation_item =>
descriptive_representation_item
descriptive_representation_item.description
```

2.2   DRILL_AND_FILL_TWIN

```
AIM element: twin_feature
Source:        10303-238
Reference path:
twin_feature <=
instanced_feature <=
feature_definition <=
characterized_object]
{characterized_object
characterized_object.description = 'drill and fill'}
```

2.2.1   drill_and_fill_twin to stack_up (as stackups)

```
AIM element: PATH
Reference path:
twin_feature <=
instanced_feature <=
shape_aspect
action_method_items = shape_aspect
action_method_items <-
applied_action_method_assignment.items[i]
applied_action_method_assignment <=
action_method_assignment
{ action_method_assignment.role ->
action_method_role
action_method_role.name = 'stack up' }
action_method_assignment.assigned_action_method ->
action_method =>
machining_stack
```

2.2.2   hole_in_place

#1: if value is true

#2: if value is false (mapping may be omitted if value is false)

```
AIM element: descriptive_representation_item.description
```

```
Source:         10303-45
Reference path:
twin_feature <=
instanced_feature <=
shape_aspect
shape_definition = shape_aspect
shape_definition
characterized_definition = shape_definition
characterized_definition <-
property_definition.definition
property_definition
{property_definition.name = 'hole present'}
represented_definition = property_definition
represented_definition <-
property_definition_representation.definition
property_definition_representation
property_definition_representation.used_representation ->
representation
representation.items[i] ->
representation_item =>
descriptive_representation_item
descriptive_representation_item.description
{ #1: (descriptive_representation_item.description = 'hole present' )
#2: (descriptive_representation_item.description = 'hole not present' ) }
```

2.2.3 pilot_hole_in_place

#1: if value is true

#2: if value is false (mapping may be omitted if value is false)

```
AIM element: descriptive_representation_item.description
Source:         10303-45
Reference path:
twin_feature <=
instanced_feature <=
shape_aspect
shape_definition = shape_aspect
shape_definition
characterized_definition = shape_definition
characterized_definition <-
property_definition.definition
property_definition
{property_definition.name = 'pilot present'}
represented_definition = property_definition
represented_definition <-
property_definition_representation.definition
property_definition_representation
property_definition_representation.used_representation ->
representation
representation.items[i] ->
representation_item =>
descriptive_representation_item
```

```
descriptive_representation_item.description
{ #1: (descriptive_representation_item.description = 'pilot present' )
#2: (descriptive_representation_item.description = 'pilot not present' ) }
```

2.2.4 drill_and_fill_twin to product_view_twin (as tack_in_place)

```
AIM element: PATH
Reference path:
twin_feature <=
instanced_feature <=
shape_aspect <-
shape_aspect_relationship.relating_shape_aspect
{shape_aspect_relationship.name = 'tack'}
{shape_aspect_relationship.description = 'product usage'}
shape_aspect_relationship
shape_aspect_relationship.related_shape_aspect ->
shape_aspect
{shape_aspect.description = 'product occurrence'}
shape_aspect.of_shape ->
product_definition_shape <=
property_definition
property_definition.definition ->
characterized_definition
characterized_definition = characterized_product_definition
characterized_product_definition
characterized_product_definition = product_definition
product_definition
```

2.2.5 drill_and_fill_twin to product_view_twin (as fastener_in_place)

```
AIM element: PATH
Reference path:
twin_feature <=
instanced_feature <=
shape_aspect <-
shape_aspect_relationship.relating_shape_aspect
{shape_aspect_relationship.name = 'fastener'}
{shape_aspect_relationship.description = 'product usage'}
shape_aspect_relationship
shape_aspect_relationship.related_shape_aspect ->
shape_aspect
{shape_aspect.description = 'product occurrence'}
shape_aspect.of_shape ->
product_definition_shape <=
property_definition
property_definition.definition ->
characterized_definition
characterized_definition = characterized_product_definition
characterized_product_definition
characterized_product_definition = product_definition
product_definition
```

2.2.6 drill_and_fill_twin to product_view_twin (as collar_in_place)

```
AIM element: PATH
Reference path:
twin_feature <=
instanced_feature <=
shape_aspect <-
shape_aspect_relationship.relating_shape_aspect
{shape_aspect_relationship.name = 'collar'}
{shape_aspect_relationship.description = 'product usage'}
shape_aspect_relationship
shape_aspect_relationship.related_shape_aspect ->
shape_aspect
{shape_aspect.description = 'product occurrence'}
shape_aspect.of_shape ->
product_definition_shape <=
property_definition
property_definition.definition ->
characterized_definition
characterized_definition = characterized_product_definition
characterized_product_definition
characterized_product_definition = product_definition
product_definition
```

2.2.7 drill_and_fill_twin to product_view_twin (as washer_in_place)

```
AIM element: PATH
Reference path:
twin_feature <=
instanced_feature <=
shape_aspect <-
shape_aspect_relationship.relating_shape_aspect
{shape_aspect_relationship.name = 'washer'}
{shape_aspect_relationship.description = 'product usage'}
shape_aspect_relationship
shape_aspect_relationship.related_shape_aspect ->
shape_aspect
{shape_aspect.description = 'product occurrence'}
shape_aspect.of_shape ->
product_definition_shape <=
property_definition
property_definition.definition ->
characterized_definition
characterized_definition = characterized_product_definition
characterized_product_definition
characterized_product_definition = product_definition
product_definition
```

2.2.8 washer_count

```
AIM element: count_measure
Source:      10303-41
```

```
Reference path:
twin_feature <=
instanced_feature <=
shape_aspect
shape_definition = shape_aspect
shape_definition
characterized_definition = shape_definition
characterized_definition <-
property_definition.definition
property_definition
{property_definition.name = 'washer count'}
represented_definition = property_definition
represented_definition <-
property_definition_representation.definition
property_definition_representation
property_definition_representation.used_representation ->
representation
representation.items[i] ->
representation_item =>
measure_representation_item <=
measure_with_unit =>
measure_with_unit.value_component ->
measure_value
measure_value = count_measure
count_measure
```

2.2.9   drill_and_fill_twin to product_view_twin (as sealed)

```
AIM element: PATH
Reference path:
twin_feature <=
instanced_feature <=
shape_aspect <-
shape_aspect_relationship.relating_shape_aspect
{shape_aspect_relationship.name = 'sealed'}
{shape_aspect_relationship.description = 'product usage'}
shape_aspect_relationship
shape_aspect_relationship.related_shape_aspect ->
shape_aspect
{shape_aspect.description = 'product occurrence'}
shape_aspect.of_shape ->
product_definition_shape <=
property_definition
property_definition.definition ->
characterized_definition
characterized_definition = characterized_product_definition
characterized_product_definition
characterized_product_definition = product_definition
product_definition
```

2.2.10 engineering_fit

```
AIM element: class.name
```

```
Source:              ISO 10303-54
Reference path:
twin_feature <=
instanced_feature <=
shape_aspect
classification_item = shape_aspect
classification_item
applied_classification_assignment.items[i] ->
applied_classification_assignment <=
classification_assignment
classification_assignment.role ->
classification_role
{ classification_role.name = 'engineering fit' }
classification_assignment.assigned_class ->
group =>
class
class.name
{ (class.name = 'loose running')
(class.name = 'free running')
(class.name = 'close running')
(class.name = 'sliding')
(class.name = 'location') }
```

2.2.11 disposition

```
AIM element: class.name
Source:              ISO 10303-54
Reference path:
twin_feature <=
instanced_feature <=
shape_aspect
classification_item = shape_aspect
classification_item
applied_classification_assignment.items[i] ->
applied_classification_assignment <=
classification_assignment
classification_assignment.role ->
classification_role
{ classification_role.name = 'disposition' }
classification_assignment.assigned_class ->
group =>
class
class.name
{ (class.name = 'pending')
(class.name = 'active')
(class.name = 'exception')
(class.name = 'hold')
(class.name = 'completed')
(class.name = 'replaced') }
```

2.2.12 drill_and_fill_twin to geometric_tolerance_twin (as true_location)

HOW CAN WE LINK THESE?

2.2.13 drill_and_fill_twin to dimensional_size_twin (as true_size)

<mark>HOW CAN WE LINK THESE?</mark>

2.2.14 drill_and_fill_twin to geometric_tolerance_twin (as true_form)

<mark>HOW CAN WE LINK THESE?</mark>

2.2.15 drill_and_fill_twin to product_view_twin (as replacement)

```
AIM element: PATH
Reference path:
twin_feature <=
instanced_feature <=
shape_aspect <-
shape_aspect_relationship.relating_shape_aspect
{shape_aspect_relationship.name = 'replacement'}
{shape_aspect_relationship.description = 'product usage'}
shape_aspect_relationship
shape_aspect_relationship.related_shape_aspect ->
shape_aspect
{shape_aspect.description = 'product occurrence'}
shape_aspect.of_shape ->
product_definition_shape <=
property_definition
property_definition.definition ->
characterized_definition
characterized_definition = characterized_product_definition
characterized_product_definition
characterized_product_definition = product_definition
product_definition
```

2.3 DRILL_AND_FILL_STACKUP

```
AIM element: machining_stack
Source:      10303-238
Reference path:
machining_stack <=
action_method
```

2.3.1 purpose

```
AIM element: descriptive_representation_item.description
Source:   10303-45
Reference path:
filling_type_operation <=
machining_operation <=
action_method
characterized_action_definition = action_method
```

```
characterized_action_definition <-
action_property.definition
{ action_property.name = 'purpose' }
action_property <-
action_property_representation.property
action_property_representation
action_property_representation.representation ->
representation representation.items[i] ->
representation_item =>
descriptive_representation_item
descriptive_representation_item.description
{ (descriptive_representation_item.description = 'designed' )
(descriptive_representation_item.description = 'assembled' )
(descriptive_representation_item.description = 'predicted' )
(descriptive_representation_item.description = 'measured' ) }
```

2.3.2 drill_and_fill_stackup to product_view_definition (as outer_part)

```
AIM element: PATH
Reference path:
machining_stack <=
action_method <-
action_method_assignment.assigned_action_method
{ action_method_assignment.role ->
action_method_role
action_method_role.name = 'outer part' }
action_method_assignment =>
applied_action_method_assignment
applied_action_method_assignment.items[i] ->
action_method_items
action_method_items = product_definition
product_definition
```

2.3.3 default_direction

```
AIM element: direction
Source:      10303-42
Reference path:
machining_stack <=
action_method
characterized_action_definition = action_method
characterized_action_definition <-
action_property.definition
{ action_property.name = 'direction' }
action_property <-
action_property_representation.property
action_property_representation
action_property_representation.representation ->
representation
representation.items[i] ->
representation_item =>
geometric_representation_item =>
direction
```

2.3.4 default_diameter

```
AIM element: length_measure_with_unit
Source:       10303-41
Reference path:
machining_stack <=
action_method
characterized_action_definition = action_method
characterized_action_definition <-
action_property.definition
{ action_property.name = 'diameter' }
action_property <-
action_property_representation.property
action_property_representation
action_property_representation.representation ->
representation
representation.items[i] ->
representation_item =>
measure_representation_item <=
measure_with_unit =>
length_measure_with_unit
```

2.3.5 drill_and_fill_stackup to stack_layer (as layers)

```
AIM element: PATH
Reference path:
machining_stack <=
action_method <-
action_method_relationship.relating_method
action_method_relationship
{ action_method_relationship =>
sequential_method }
action_method_relationship.related_method ->
action_method =>
machining_stack_element
```

2.3.6 computed_depth

```
AIM element: length_measure_with_unit
Source:       10303-41
Reference path:
machining_stack <=
action_method
characterized_action_definition = action_method
characterized_action_definition <-
action_property.definition
{ action_property.name = 'computed depth' }
action_property <-
action_property_representation.property
action_property_representation
action_property_representation.representation ->
representation
```

```
representation.items[i] ->
representation_item =>
measure_representation_item <=
measure_with_unit =>
length_measure_with_unit
```

2.3.7 when_computed

```
AIM element: date_and_time
Source:        10303-41
Reference path:
machining_stack <=
action_method
date_and_time_item = action_method
date_and_time_item <-
applied_date_and_time_assignment.items[i]
applied_date_and_time_assignment <=
date_and_time_assignment
{ date_and_time_assignment.role ->
date_time_role
date_time_role.name = 'when computed' }
date_and_time_assignment.assigned_date_and_time ->
date_and_time
```

2.4 STACK_LAYER

```
AIM element: machining_stack_element
Source:        10303-238
Reference path:
machining_stack_element <=
action_method
```

2.4.1 stack_layer to product_view_definition (as usage)

```
AIM element: PATH
Reference path:
machining_stack_element <=
action_method <-
action_method_assignment.assigned_action_method
{ action_method_assignment.role ->
action_method_role
action_method_role.name = 'usage' }
action_method_assignment =>
applied_action_method_assignment
applied_action_method_assignment.items[i] ->
action_method_items
action_method_items = product_definition
product_definition
```

2.4.2 start_dist

```
AIM element: length_measure_with_unit
Source:       10303-41
Reference path:
machining_stack_element <=
action_method
characterized_action_definition = action_method
characterized_action_definition <-
action_property.definition
{ action_property.name = ' start distance' }
action_property <-
action_property_representation.property
action_property_representation
action_property_representation.representation ->
representation
representation.items[i] ->
representation_item =>
measure_representation_item` <=
measure_with_unit =>
length_measure_with_unit
```

2.4.3 end_dist

```
AIM element: length_measure_with_unit
Source:       10303-41
Reference path:
machining_stack_element <=
action_method
characterized_action_definition = action_method
characterized_action_definition <-
action_property.definition
{ action_property.name = 'end distance' }
action_property <-
action_property_representation.property
action_property_representation
action_property_representation.representation ->
representation
representation.items[i] ->
representation_item =>
measure_representation_item <=
measure_with_unit =>
length_measure_with_unit
```

2.4.4 status

```
AIM element: descriptive_representation_item.description
Source:       10303-45
Reference path:
machining_stack_element <=
action_method
characterized_action_definition = action_method
```

```
characterized_action_definition <-
action_property.definition
{ action_property.name = 'status' }
action_property <-
action_property_representation.property
action_property_representation
action_property_representation.representation ->
representation
representation.items[i] ->
representation_item =>
descriptive_representation_item
descriptive_representation_item.description
{ (descriptive_representation_item.description = 'air gap')
(descriptive_representation_item.description = 'overlap') }
```

2.4.5 stack_layer to manufacturing_feature (as layer_feature)

```
AIM element: PATH
Reference path:
machining_stack_element <=
action_method <-
action_method_assignment.assigned_action_method
{ action_method_assignment.role ->
action_method_role
action_method_role.name = 'layer feature' }
action_method_assignment =>
applied_action_method_assignment
applied_action_method_assignment.items[i] ->
action_method_items
action_method_items = shape_aspect
shape_aspect =>
instanced_feature <=
feature_definition
```

3 Product and Tolerance Twin Mapping specification

3.1 PRODUCT_VIEW_TWIN

```
AIM element: product_definition
Source:      10303-41
Reference path:
product_definition
characterized_product_definition = product_definition
characterized_product_definition
characterized_definition = characterized_product_definition
characterized_definition <-
property_definition.definition
{ property_definition =>
product_definition_shape }
property_definition <-
```

```
property_definition_relationship.relating_property_definition
property_definition_relationship
{ property_definition_relationship =>
twin_prototype_relationship }
```

3.1.1 product_view_twin to product_view_definition (as prototype)

```
AIM element: PATH
Reference path:
product_definition
characterized_product_definition = product_definition
characterized_product_definition
characterized_definition = characterized_product_definition
characterized_definition <-
property_definition.definition
{ property_definition =>
product_definition_shape }
property_definition <-
property_definition_relationship.relating_property_definition
property_definition_relationship
{ property_definition_relationship =>
twin_prototype_relationship }
property_definition_relationship.related_property_definition ->
property_definition
{ property_definition =>
product_definition_shape }
property_definition.definition -
characterized_definition
characterized_definition = characterized_product_definition
characterized_product_definition
characterized_product_definition = product_definition
product_definition
```

3.1.2 serial_number

```
AIM element: product_definition.id
Source:       10303-41
Reference path:
product_definition
product_definition.id
```

3.1.3 envelope

```
AIM element: shape_representation_with_parameters
Source:       10303-47
Reference path:
product_definition
characterized_product_definition = product_definition
characterized_product_definition
characterized_definition = characterized_product_definition
characterized_definition <-
property_definition.definition
```

```
{property_definition =>
product_definition_shape}
property_definition <-
represented_definition = property_definition
represented_definition <-
property_definition_representation.definition
{property_definition_representation =>
shape_definition_representation}
property_definition_representation
property_definition_representation.used_representation ->
representation =>
shape_representation =>
shape_representation_with_parameters
```

3.1.4 when

```
AIM element:  date_and_time
Source:        10303-41
Reference path:
product_definition
date_and_time_item = product_definition
date_and_time_item <-
applied_date_and_time_assignment.items[i]
applied_date_and_time_assignment <=
date_and_time_assignment
{ date_and_time_assignment.role ->
date_time_role
date_time_role.name = 'measured' }
date_and_time_assignment.assigned_date_and_time ->
date_and_time
```

3.1.5 role

```
AIM element:  descriptive_representation_item.description
Source:        10303-45
Reference path:
product_definition
characterized_product_definition = product_definition
characterized_product_definition
characterized_definition = characterized_product_definition
characterized_definition <-
property_definition.definition
property_definition <-
{property_definition.name = 'role'}
represented_definition = property_definition
represented_definition <-
property_definition_representation.definition
property_definition_representation
property_definition_representation.used_representation ->
representation
representation.items[i] ->
representation_item =>
descriptive_representation_item
```

```
descriptive_representation_item.description
```

3.2 PRODUCT_VIEW_TWIN_WITH_SUPPLIER_DEFINITION

```
AIM element: product_definition
Source:      10303-41
Reference path:
product_definition
{ product_definition
organization_item = product_definition
organization_item <-
applied_organization_assignment.items[i]
applied_organization_assignment <=
organization_assignment
organization_assignment.role ->
organization_role
organization_role.name = 'supplier' }
```

3.2.1 supplier_cage_code

```
AIM element: organization.id
Source:      10303-41
Reference path:
product_definition
organization_item = product_definition
organization_item <-
applied_organization_assignment.items[i]
applied_organization_assignment <=
organization_assignment
{ organization_assignment.role ->
organization_role
organization_role.name = 'supplier' }
organization_assignment.assigned_organization ->
organization
organization.id
```

3.3 PRODUCT_VIEW_TWIN_WITH_MANUFACTURING_DEFINITION

```
AIM element: product_definition
Source:      10303-41
Reference path:
product_definition
```

NO IDEA HOW TO DISTINGUISH THIS SINCE EVERYTHING IS OPTIONAL

3.3.1 product_view_twin_with_manufacturing_definition to workplan (as manufacturing_prototype)

```
AIM element: PATH
```

```
Reference path:
product_definition
action_method_items = product_definition
action_method_items <-
applied_action_method_assignment.items[i]
applied_action_method_assignment <=
action_method_assignment
{ action_method_assignment.role ->
action_method_role
action_method_role.name = 'manufacturing prototype' }
action_method_assignment.assigned_action_method ->
action_method =>
machining_process_executable =>
machining_workplan
```

3.3.2 manufacturing_serial_number

```
AIM element: identification_assignment.assigned_id
Source:        10303-41
Reference path:
product_definition
identification_item = product_definition
identification_item <-
applied_identification_assignment.items[i]
applied_identification_assignment <=
identification_assignment
{ action_method_assignment.role ->
identification_role
identification_role.name = 'manufacturing serial number' }
identification_assignment.assigned_id
```

3.3.3 product_view_twin_with_manufacturing_definition to workplan (as completed_operations)

```
AIM element: PATH
Reference path:
product_definition
action_method_items = product_definition
action_method_items <-
applied_action_method_assignment.items[i]
applied_action_method_assignment <=
action_method_assignment
{ action_method_assignment.role ->
action_method_role
action_method_role.name = 'completed operations' }
action_method_assignment.assigned_action_method ->
action_method =>
machining_process_executable =>
machining_workplan
```

3.3.4 product_view_twin_with_manufacturing_definition to trajectory (as discrepancies)

```
AIM element: PATH
Reference path:
product_definition
action_method_items = product_definition
action_method_items <-
applied_action_method_assignment.items[i]
applied_action_method_assignment <=
action_method_assignment
{ action_method_assignment.role ->
action_method_role
action_method_role.name = 'discrepancy' }
action_method_assignment.assigned_action_method ->
action_method =>
machining_toolpath
```

3.4 PRODUCT_VIEW_TWIN_WITH_MANUFACTURING_PURPOSE

3.4.1 product_view_twin_with_manufacturing_purpose to workplan (as planned_operations)

```
AIM element: PATH
Reference path:
product_definition
action_method_items = product_definition
action_method_items <-
applied_action_method_assignment.items[i]
applied_action_method_assignment <=
action_method_assignment
{ action_method_assignment.role ->
action_method_role
action_method_role.name = 'planned operations' }
action_method_assignment.assigned_action_method ->
action_method =>
machining_process_executable =>
machining_workplan
```

3.4.2 resource_serial_number

```
AIM element: identification_assignment.assigned_id
Source:      10303-41
Reference path:
product_definition
identification_item = product_definition
identification_item <-
applied_identification_assignment.items[i]
applied_identification_assignment <=
identification_assignment
{ action_method_assignment.role ->
identification_role
```

```
identification_role.name = 'resource serial number' }
identification_assignment.assigned_id
```

3.4.3 product_view_twin_with_manufacturing_purpose to workplan (as machined_operations)

```
AIM element: PATH
Reference path:
product_definition
action_method_items = product_definition
action_method_items <-
applied_action_method_assignment.items[i]
applied_action_method_assignment <=
action_method_assignment
{ action_method_assignment.role ->
action_method_role
action_method_role.name = 'machined operations' }
action_method_assignment.assigned_action_method ->
action_method =>
machining_process_executable =>
machining_workplan
```

3.4.4 product_view_twin_with_manufacturing_purpose to trajectory (as discrepancies)

```
AIM element: PATH
Reference path:
product_definition
action_method_items = product_definition
action_method_items <-
applied_action_method_assignment.items[i]
applied_action_method_assignment <=
action_method_assignment
{ action_method_assignment.role ->
action_method_role
action_method_role.name = 'discrepancy' }
action_method_assignment.assigned_action_method ->
action_method =>
machining_toolpath
```

3.5 GEOMETRIC_TOLERANCE_TWIN

```
AIM element: geometric_tolerance
Source:      10303-47
Reference path:
geometric_tolerance
characterized_item = geometric_tolerance
characterized_item
characterized_definition = characterized_item
characterized_definition <-
property_definition.definition
property_definition <-
```

```
property_definition_relationship.relating_property_definition
property_definition_relationship
{ property_definition_relationship =>
twin_prototype_relationship }
```

3.5.1 geometric_tolerance_twin to geometric_tolerance (as prototype)

```
AIM element: PATH
Reference path:
geometric_tolerance
characterized_item = geometric_tolerance
characterized_item
characterized_definition = characterized_item
characterized_definition <-
property_definition.definition
property_definition <-
property_definition_relationship.relating_property_definition
property_definition_relationship
{ property_definition_relationship =>
twin_prototype_relationship }
property_definition_relationship.related_property_definition ->
property_definition
property_definition.definition ->
characterized_definition
characterized_definition = characterized_item
characterized_item
characterized_item = geometric_tolerance
geometric_tolerance
```

3.5.2 geometric_tolerance_twin to product_view_twin (as twin_product)

```
AIM element: PATH
Reference path:
geometric_tolerance
geometric_tolerance.toleranced_shape_aspect ->
geometric_tolerance_target = product_definition_shape
product_definition_shape <=
property_definition
property_definition.definition ->
characterized_definition
characterized_definition = characterized_product_definition
characterized_product_definition
characterized_product_definition = product_definition
product_definition
```

3.6 DIMENSIONAL_SIZE_TWIN

```
AIM element: dimensional_size
Source:        10303-47
Reference path:
dimensional_size
```

```
characterized_item = geometric_tolerance
characterized_item
characterized_definition = characterized_item
characterized_definition <-
property_definition.definition
property_definition <-
property_definition_relationship.relating_property_definition
property_definition_relationship
{ property_definition_relationship =>
twin_prototype_relationship }
```

3.6.1 dimensional_size_twin to dimensional_size (as prototype)

```
AIM element: PATH
Reference path:
dimensional_size
characterized_item = geometric_tolerance
characterized_item
characterized_definition = characterized_item
characterized_definition <-
property_definition.definition
property_definition <-
property_definition_relationship.relating_property_definition
property_definition_relationship
{ property_definition_relationship =>
twin_prototype_relationship }
property_definition_relationship.related_property_definition ->
property_definition
property_definition.definition ->
characterized_definition
characterized_definition = characterized_item
characterized_item
characterized_item = geometric_tolerance
dimensional_size
```

3.6.2 dimensional_size_twin to product_view_twin (as twin_product)

```
AIM element: PATH
Reference path:
dimensional_size <=
shape_aspect
shape_aspect.of_shape ->
product_definition_shape <=
property_definition
property_definition.definition ->
characterized_definition
characterized_definition = characterized_product_definition
characterized_product_definition
characterized_product_definition = product_definition
product_definition
```

3.7 DIMENSIONAL_LOCATION_TWIN

```
AIM element: dimensional_location
Source:        10303-47
Reference path:
dimensional_location <=
shape_aspect_relationship
shape_definition = shape_aspect_relationship
shape_definition
characterized_definition = shape_definition
characterized_definition <-
property_definition.definition
property_definition <-
property_definition_relationship.relating_property_definition
property_definition_relationship
{ property_definition_relationship =>
twin_prototype_relationship }
```

3.7.1 dimensional_location_twin to dimensional_location (as prototype)

```
AIM element: PATH
Reference path:
AIM element: dimensional_location
Source:        10303-47
Reference path:
dimensional_location <=
shape_aspect_relationship
shape_definition = shape_aspect_relationship
shape_definition
characterized_definition = shape_definition
characterized_definition <-
property_definition.definition
property_definition <-
property_definition_relationship.relating_property_definition
property_definition_relationship
{ property_definition_relationship =>
twin_prototype_relationship }
property_definition_relationship.related_property_definition ->
property_definition
property_definition.definition ->
characterized_definition
characterized_definition = shape_definition
shape_definition
shape_definition = shape_aspect_relationship
shape_aspect_relationship =>
dimensional_location
```

3.7.2 dimensional_location_twin to product_view_twin (as source_twin_product)

```
AIM element: PATH
Reference path:
dimensional_location <=
```

```
shape_aspect_relationship
shape_aspect_relationship.relating_shape_aspect ->
shape_aspect
shape_aspect.of_shape ->
product_definition_shape <=
property_definition
property_definition.definition ->
characterized_definition
characterized_definition = characterized_product_definition
characterized_product_definition
characterized_product_definition = product_definition
product_definition
```

3.7.3 dimensional_location_twin to product_view_twin (as target_twin_product)

```
AIM element: PATH
Reference path:
dimensional_location <=
shape_aspect_relationship
shape_aspect_relationship.related_shape_aspect ->
shape_aspect
shape_aspect.of_shape ->
product_definition_shape <=
property_definition
property_definition.definition ->
characterized_definition
characterized_definition = characterized_product_definition
characterized_product_definition
characterized_product_definition = product_definition
product_definition
```

4 Groups Mapping specification

4.1 DRILL_AND_FILL_GROUP

```
AIM element: filling_type_group
Source:      10303-238
Reference path:
filling_type_group <=
machining_group <=
[group]
[characterized_object]
```

4.1.1 manufacturing_stage

```
AIM element: descriptive_representation_item.description
Source:      10303-45
Reference path:
filling_type_group <=
```

```
machining_group <=
characterized_object
characterized_definition = characterized_object
characterized_definition <-
property_definition.definition
property_definition
{property_definition.name = 'manufacturing stage'}
represented_definition = property_definition
represented_definition <-
property_definition_representation.definition
property_definition_representation
property_definition_representation.used_representation ->
representation
representation.items[i]->
representation_item =>
descriptive_representation_item
descriptive_representation_item.description
```

4.1.2 primary

#1: if value is true

#2: if value is false (mapping may be omitted if value is false)

```
AIM element: descriptive_representation_item.description
Source:       10303-45
Reference path:
filling_type_group <=
machining_group <=
characterized_object
characterized_definition = characterized_object
characterized_definition <-
property_definition.definition
property_definition
{property_definition.name = 'manufacturing stage'}
represented_definition = property_definition
represented_definition <-
property_definition_representation.definition
property_definition_representation
property_definition_representation.used_representation ->
representation
representation.items[i]->
representation_item =>
descriptive_representation_item
descriptive_representation_item.description
 { #1: (descriptive_representation_item.description = 'primary' )
 #2: (descriptive_representation_item.description = 'secondary' ) }
```

4.2 REFERENCE_FRAME_GROUP

```
AIM element: filling_type_group
```

```
Source:         10303-238
Reference path:
filling_type_group <=
machining_group <=
[group]
[characterized_object]
```

4.2.1 guide_verified

#1: if value is true

#2: if value is false (mapping may be omitted if value is false)

```
AIM element: descriptive_representation_item.description
Source:         10303-45
Reference path:
filling_type_group <=
machining_group <=
characterized_object
characterized_definition = characterized_object
characterized_definition <-
property_definition.definition
property_definition
{property_definition.name = 'guide verified'}
represented_definition = property_definition
represented_definition <-
property_definition_representation.definition
property_definition_representation
property_definition_representation.used_representation ->
representation
representation.items[i]->
representation_item =>
descriptive_representation_item
descriptive_representation_item.description
{ #1: (descriptive_representation_item.description = 'verified' )
#2: (descriptive_representation_item.description = 'not verified' ) }
```

4.2.2 reference_frame_group to reference_frame_group (as basis)

```
AIM element: PATH
Reference path:
filling_type_group <=
machining_group <=
group <-
group_relationship.relating_group
group_relationship
{ group_relationship.name = 'basis' }
group_relationship.related_group ->
group =>
machining_group =>
filling_type_group
```

4.2.3 modification

```
AIM element: axis2_placement_3d
Source:       10303-42
Reference path:
filling_type_group <=
machining_group <=
characterized_object
characterized_definition = characterized_object
characterized_definition <-
property_definition.definition
property_definition
{property_definition.name = 'modification'}
represented_definition = property_definition
represented_definition <-
property_definition_representation.definition
property_definition_representation
property_definition_representation.used_representation ->
representation
representation.items[i]->
representation_item =>
geometric_representation_item =>
placement =>
axis2_placement_3d
```

4.2.4 verification_time

```
AIM element: date_and_time
Source:       10303-41
Reference path:
filling_type_group <=
machining_group
date_and_time_item = machining_group
date_and_time_item <-
applied_date_and_time_assignment.items[i]
applied_date_and_time_assignment <=
date_and_time_assignment
{ date_and_time_assignment.role ->
date_time_role
date_time_role.name = 'verification time' }
date_and_time_assignment.assigned_date_and_time ->
date_and_time
```

4.3 THREE_TWIN_REFERENCE_FRAME_GROUP

```
AIM element: filling_type_group
Source:       10303-238
Reference path:
filling_type_group <=
machining_group <=
group
group.description
```

```
{ group.description = 'three twin reference frame' }
```

4.3.1 three_twin_reference_frame_group to drill_and_fill_twin (as guide_primary)

```
AIM element: PATH
Reference path:
filling_type_group <=
machining_group <=
group <-
group_assignment.assigned_group
{ group_assignment <-
role_select = group_assignment
role_select <-
role_association.item_with_role
role_association
role_association.role ->
object_role
object_role.name = 'primary guide' }
group_assignment =>
applied_group_assignment
applied_group_assignment.items[i] ->
groupable_item
groupable_item = shape_aspect
shape_aspect =>
instanced_feature =>
twin_feature
```

4.3.2 three_twin_reference_frame_group to drill_and_fill_twin (as guide_secondary)

```
AIM element: PATH
Reference path:
filling_type_group <=
machining_group <=
group <-
group_assignment.assigned_group
{ group_assignment <-
role_select = group_assignment
role_select <-
role_association.item_with_role
role_association
role_association.role ->
object_role
object_role.name = 'secondary guide' }
group_assignment =>
applied_group_assignment
applied_group_assignment.items[i] ->
groupable_item
groupable_item = shape_aspect
shape_aspect =>
instanced_feature =>
twin_feature
```

4.3.3 three_twin_reference_frame_group to drill_and_fill_twin (as guide_tertiary)

```
AIM element: PATH
Reference path:
filling_type_group <=
machining_group <=
group <-
group_assignment.assigned_group
{ group_assignment <-
role_select = group_assignment
role_select <-
role_association.item_with_role
role_association
role_association.role ->
object_role
object_role.name = 'tertiary guide' }
group_assignment =>
applied_group_assignment
applied_group_assignment.items[i] ->
groupable_item
groupable_item = shape_aspect
shape_aspect =>
instanced_feature =>
twin_feature
```

4.4 BEST_FIT_REFERENCE_FRAME_GROUP

```
AIM element: filling_type_group
Source:        10303-238
Reference path:
filling_type_group <=
machining_group <=
group
group.description
{ group.description = 'best fit reference frame' }
```

4.4.1 best_fit_reference_frame_group to drill_and_fill_twin (as guides)

```
AIM element: PATH
Reference path:
filling_type_group <=
machining_group <=
group <-
group_assignment.assigned_group
{ group_assignment <-
role_select = group_assignment
role_select <-
role_association.item_with_role
role_association
role_association.role ->
object_role
object_role.name = 'guides' }
```

```
group_assignment =>
applied_group_assignment
applied_group_assignment.items[i] ->
groupable_item
groupable_item = shape_aspect
shape_aspect =>
instanced_feature =>
twin_feature
```

4.5 FASTENER_GROUP

```
AIM element: filling_type_group
Source:        10303-238
Reference path:
filling_type_group <=
machining_group <=
group
group.description
{ group.description = 'fastener' }
```

4.5.1 maximum_grip_length

```
AIM element: length_measure_with_unit
Source:        10303-41
Reference path:
filling_type_group <=
machining_group <=
characterized_object
characterized_definition = characterized_object
characterized_definition <-
property_definition.definition
property_definition
{property_definition.name = 'maximum grip length'}
represented_definition = property_definition
represented_definition <-
property_definition_representation.definition
property_definition_representation
property_definition_representation.used_representation ->
representation
representation.items[i]->
representation_item =>
measure_representation_item <=
measure_with_unit =>
length_measure_with_unit
```

4.5.2 minimum_grip_length

```
AIM element: length_measure_with_unit
Source:        10303-41
Reference path:
filling_type_group <=
```

```
machining_group <=
characterized_object
characterized_definition = characterized_object
characterized_definition <-
property_definition.definition
property_definition
{property_definition.name = 'minimum grip length'}
represented_definition = property_definition
represented_definition <-
property_definition_representation.definition
property_definition_representation
property_definition_representation.used_representation ->
representation
representation.items[i]->
representation_item =>
measure_representation_item <=
measure_with_unit =>
length_measure_with_unit
```

4.5.3 fastener_group to product_view_definition (as fastener)

```
AIM element: PATH
Reference path:
filling_type_group <=
machining_group <=
group <-
group_assignment.assigned_group
{ group_assignment <-
role_select = group_assignment
role_select <-
role_association.item_with_role
role_association
role_association.role ->
object_role
object_role.name = 'fastener' }
group_assignment =>
applied_group_assignment
applied_group_assignment.items[i] ->
groupable_item
groupable_item = product_definition
product_definition
```

4.5.4 fastener_group to product_view_definition (as collar)

```
AIM element: PATH
Reference path:
filling_type_group <=
machining_group <=
group <-
group_assignment.assigned_group
{ group_assignment <-
role_select = group_assignment
role_select <-
```

```
role_association.item_with_role
role_association
role_association.role ->
object_role
object_role.name = 'collar' }
group_assignment =>
applied_group_assignment
applied_group_assignment.items[i] ->
groupable_item
groupable_item = product_definition
product_definition
```

4.5.5 fastener_group to product_view_definition (as sealant)

```
AIM element: PATH
Reference path:
filling_type_group <=
machining_group <=
group <-
group_assignment.assigned_group
{ group_assignment <-
role_select = group_assignment
role_select <-
role_association.item_with_role
role_association
role_association.role ->
object_role
object_role.name = 'sealant' }
group_assignment =>
applied_group_assignment
applied_group_assignment.items[i] ->
groupable_item
groupable_item = product_definition
product_definition
```

4.5.6 fastener_group to product_view_definition (as washer)

```
AIM element: PATH
Reference path:
filling_type_group <=
machining_group <=
group <-
group_assignment.assigned_group
{ group_assignment <-
role_select = group_assignment
role_select <-
role_association.item_with_role
role_association
role_association.role ->
object_role
object_role.name = 'washer' }
group_assignment =>
applied_group_assignment
```

```
applied_group_assignment.items[i] ->
groupable_item
groupable_item = product_definition
product_definition
```

4.5.7 washer_count

```
AIM element: count_measure
Source:        10303-41
Reference path:
filling_type_group <=
machining_group <=
characterized_object
characterized_definition = characterized_object
characterized_definition <-
property_definition.definition
property_definition
{property_definition.name = 'washer count'}
represented_definition = property_definition
represented_definition <-
property_definition_representation.definition
property_definition_representation
property_definition_representation.used_representation ->
representation
representation.items[i] ->
representation_item =>
measure_representation_item <=
measure_with_unit =>
measure_with_unit.value_component ->
measure_value
measure_value = count_measure
count_measure
```

4.6 ONEUP_ASSEMBLY_GROUP

```
AIM element: filling_type_group
Source:        10303-238
Reference path:
filling_type_group <=
machining_group <=
group
group.description
{ group.description = 'oneup' }
```

4.6.1 oneup_assembly_group to workplan (as manufacturing_plan)

```
AIM element: PATH
Reference path:
filling_type_group <=
machining_group <=
characterized_object
```

```
action_method_items = characterized_object
action_method_items <-
applied_action_method_assignment.items[i]
applied_action_method_assignment <=
action_method_assignment
{ action_method_assignment.role ->
action_method_role
action_method_role.name = 'plan' }
action_method_assignment.assigned_action_method ->
action_method =>
machining_process_executable =>
machining_workplan
```

4.6.2 oneup_assembly_group to machine_with_kinematics (as compatible_robots)

```
AIM element: PATH
Reference path:
filling_type_group <=
machining_group <=
group <-
group_assignment.assigned_group
{ group_assignment <-
role_select = group_assignment
role_select <-
role_association.item_with_role
role_association
role_association.role ->
object_role
object_role.name = 'compatible robot' }
group_assignment =>
applied_group_assignment
applied_group_assignment.items[i] ->
groupable_item
groupable_item = product_definition
product_definition
```

4.6.3 oneup_assembly_group to oneup_assembly_group (as must_follow)

```
AIM element: PATH
Reference path:
filling_type_group <=
machining_group <=
group <-
group_relationship.relating_group
group_relationship
{ group_relationship.name = 'must follow' }
group_relationship.related_group ->
group =>
machining_group =>
filling_type_group
```

4.7 PREFERRED_ROBOT_GROUP

```
AIM element: filling_type_group
Source:       10303-238
Reference path:
filling_type_group <=
machining_group <=
group
group.description
{ group.description = 'preferred robot' }
```

4.7.1 preferred_robot_group to machine_with_kinematics (as preferred_robot)

```
AIM element: PATH
Reference path:
filling_type_group <=
machining_group <=
group <-
group_assignment.assigned_group
{ group_assignment <-
role_select = group_assignment
role_select <-
role_association.item_with_role
role_association
role_association.role ->
object_role
object_role.name = 'preferred robot' }
group_assignment =>
applied_group_assignment
applied_group_assignment.items[i] ->
groupable_item
groupable_item = product_definition
product_definition
```

4.7.2 precedence

```
AIM element: count_measure
Source:       10303-41
Reference path:
filling_type_group <=
machining_group <=
characterized_object
characterized_definition = characterized_object
characterized_definition <-
property_definition.definition
property_definition
{property_definition.name = 'precedence'}
represented_definition = property_definition
represented_definition <-
property_definition_representation.definition
property_definition_representation
property_definition_representation.used_representation ->
```

```
representation
representation.items[i] ->
representation_item =>
measure_representation_item <=
measure_with_unit =>
measure_with_unit.value_component ->
measure_value
measure_value = count_measure
count_measure
```

4.8   ESCAPE_SEQUENCE_GROUP

```
AIM element: filling_type_group
Source:       10303-238
Reference path:
filling_type_group <=
machining_group <=
group
group.description
{ group.description = 'escape' }
```

4.8.1   escape_sequence_group to machine_with_kinematics (as robot)

```
AIM element: PATH
Reference path:
filling_type_group <=
machining_group <=
group <-
group_assignment.assigned_group
{ group_assignment <-
role_select = group_assignment
role_select <-
role_association.item_with_role
role_association
role_association.role ->
object_role
object_role.name = 'robot' }
group_assignment =>
applied_group_assignment
applied_group_assignment.items[i] ->
groupable_item
groupable_item = product_definition
product_definition
```

4.8.2   escape_sequence_group to connect_escape_stack (as escape_moves)

```
AIM element: PATH
Reference path:
filling_type_group <=
machining_group <=
group <-
```

```
group_assignment.assigned_group
{ group_assignment <-
role_select = group_assignment
role_select <-
role_association.item_with_role
role_association
role_association.role ->
object_role
object_role.name = 'moves' }
group_assignment =>
applied_group_assignment
applied_group_assignment.items[i] ->
groupable_item
groupable_item = action_method
action_method =>
machining_toolpath
```

4.9   REQUIREMENT_AND_PROPERTY_GROUP

```
AIM element: filling_type_group
Source:        10303-238
Reference path:
filling_type_group <=
machining_group <=
group
group.description
{ group.description = 'requirement' }
```

4.9.1   requirement_and_property_group to requirement_assignment (as requirements)

```
AIM element: PATH
Reference path:
filling_type_group <=
machining_group <=
group <-
group_assignment.assigned_group
{ group_assignment <-
role_select = group_assignment
role_select <-
role_association.item_with_role
role_association
role_association.role ->
object_role
object_role.name = 'required' }
group_assignment =>
applied_group_assignment
applied_group_assignment.items[i] ->
groupable_item
groupable_item = requirement_assignment
requirement_assignment
```

4.9.2 requirement_and_property_group to assigned_property (as properties)

```
AIM element: PATH
Reference path:
filling_type_group <=
machining_group <=
group <-
group_assignment.assigned_group
{ group_assignment <-
role_select = group_assignment
role_select <-
role_association.item_with_role
role_association
role_association.role ->
object_role
object_role.name = 'properties' }
group_assignment =>
applied_group_assignment
applied_group_assignment.items[i] ->
groupable_item
groupable_item = property_definition
property_definition
```

4.9.3 when_met

```
AIM element: descriptive_representation_item.description
Source:      10303-45
Reference path:
filling_type_group <=
machining_group <=
characterized_object
characterized_definition = characterized_object
characterized_definition <-
property_definition.definition
property_definition
{property_definition.name = 'maximum grip length'}
represented_definition = property_definition
represented_definition <-
property_definition_representation.definition
property_definition_representation
property_definition_representation.used_representation ->
representation
representation.items[i]->
representation_item =>
measure_representation_item <=
measure_with_unit =>
(descriptive_representation_item.description = 'pre condition' )
(descriptive_representation_item.description = 'post condition' )
(descriptive_representation_item.description = 'pre and post condition' )
```

5 Operations Mapping specification

5.1 FILL_TYPE_OPERATION

```
AIM element: filling_type_operation
Source:      10303-238
Reference path:
filling_type_operation <=
machining_operation <=
action_method
```

5.2 CLAMP_PRODUCT_OPERATION

```
AIM element: filling_type_operation
Source:      10303-238
Reference path:
filling_type_operation <=
machining_operation <=
action_method
{ action_method.description = 'clamp product' }
```

5.2.1 clamp_product_operation to product_view_definition (as clamped_item)

```
AIM element: PATH
Reference path:
filling_type_operation <=
machining_operation <=
action_method <-
action_method_assignment.assigned_action_method
{ action_method_assignment.role ->
action_method_role
action_method_role.name = 'clamped item' }
action_method_assignment =>
applied_action_method_assignment
applied_action_method_assignment.items[i] ->
action_method_items
action_method_items = product_definition
product_definition
```

5.2.2 force

```
AIM element: measure_with_unit
Source:    10303-41
Reference path:
filling_type_operation <=
machining_operation <=
action_method
characterized_action_definition = action_method
characterized_action_definition <-
```

```
action_property.definition
{ action_property.name = 'clamp force' }
action_property <-
action_property_representation.property
action_property_representation
action_property_representation.representation ->
representation
representation.items[i] ->
representation_item =>
measure_representation_item <=
measure_with_unit
{ measure_with_unit.value_component ->
measure_value
measure_value = numeric_measure
numeric_measure }
```

5.2.3 high_speed

#1: if value is true

#2: if value is false (mapping may be omitted if value is false)

```
AIM element: descriptive_representation_item.description
Source:     10303-45
Reference path:
filling_type_operation <=
machining_operation <=
action_method
characterized_action_definition = action_method
characterized_action_definition <-
action_property.definition
{ action_property.name = 'clamp speed' }
action_property <-
action_property_representation.property
action_property_representation
action_property_representation.representation ->
representation representation.items[i] ->
representation_item =>
descriptive_representation_item
descriptive_representation_item.description
{ #1: (descriptive_representation_item.description = 'high' )
#2: (descriptive_representation_item.description = 'normal' ) }
```

5.3 FASTEN_WITH_CODES

```
AIM element: filling_type_operation
Source:      10303-238
Reference path:
filling_type_operation <=
machining_operation <=
action_method
```

```
{ action_method.description = 'codes' }
```

5.3.1 pass_thru_codes

```
AIM element: descriptive_representation_item.description
Source:    10303-45
Reference path:
filling_type_operation <=
machining_operation <=
action_method
characterized_action_definition = action_method
characterized_action_definition <-
action_property.definition
{ action_property.name = 'codes' }
action_property <-
action_property_representation.property
action_property_representation
action_property_representation.representation ->
representation
representation.items[i] ->
representation_item =>
compound_representation_item
compound_representation_item.item_element ->
compound_item_definition
compound_item_definition = list_representation_item
list_representation_item[i] ->
representation_item =>
descriptive_representation_item
descriptive_representation_item.description
```

5.4 PLACE_ITEM_OPERATION

```
AIM element: filling_type_operation
Source:        10303-238
Reference path:
filling_type_operation <=
machining_operation <=
action_method
{ (action_method.description = 'place fastener')
(action_method.description = 'place tack')
(action_method.description = 'place washer')
(action_method.description = 'place collar') }
```

5.4.1 place_item_operation to product_view_definition (as placed_item)

```
AIM element: PATH
Reference path:
filling_type_operation <=
machining_operation <=
action_method <-
action_method_assignment.assigned_action_method
```

```
{ action_method_assignment.role ->
action_method_role
action_method_role.name = 'placed item' }
action_method_assignment =>
applied_action_method_assignment
applied_action_method_assignment.items[i] ->
action_method_items
action_method_items = product_definition
product_definition
```

5.4.2 depth

```
AIM element: length_measure_with_unit
Source:    10303-41
Reference path:
filling_type_operation <=
machining_operation <=
action_method
characterized_action_definition = action_method
characterized_action_definition <-
action_property.definition
{ action_property.name = 'depth' }
action_property <-
action_property_representation.property
action_property_representation
action_property_representation.representation ->
representation
representation.items[i] ->
representation_item =>
measure_representation_item <=
measure_with_unit =>
length_measure_with_unit
```

5.4.3 minimum_force

```
AIM element: measure_with_unit
Source:    10303-41
Reference path:
filling_type_operation <=
machining_operation <=
action_method
characterized_action_definition = action_method
characterized_action_definition <-
action_property.definition
{ action_property.name = 'minimum force' }
action_property <-
action_property_representation.property
action_property_representation
action_property_representation.representation ->
representation
representation.items[i] ->
representation_item =>
measure_representation_item <=
```

```
measure_with_unit
{ measure_with_unit.value_component ->
measure_value
measure_value = numeric_measure
numeric_measure }
```

5.4.4 maximum_force

```
AIM element: measure_with_unit
Source:    10303-41
Reference path:
filling_type_operation <=
machining_operation <=
action_method
characterized_action_definition = action_method
characterized_action_definition <-
action_property.definition
{ action_property.name = 'maximum force' }
action_property <-
action_property_representation.property
action_property_representation
action_property_representation.representation ->
representation
representation.items[i] ->
representation_item =>
measure_representation_item <=
measure_with_unit
{ measure_with_unit.value_component ->
measure_value
measure_value = numeric_measure
numeric_measure }
```

5.5 PLACE_FASTENER_OPERATION

```
AIM element: filling_type_operation
Source:        10303-238
Reference path:
filling_type_operation <=
machining_operation <=
action_method
{ action_method.description = 'place fastener' }
```

5.5.1 diameter

```
AIM element: length_measure_with_unit
Source:    10303-41
Reference path:
filling_type_operation <=
machining_operation <=
action_method
characterized_action_definition = action_method
```

```
characterized_action_definition <-
action_property.definition
{ action_property.name = 'diameter' }
action_property <-
action_property_representation.property
action_property_representation
action_property_representation.representation ->
representation
representation.items[i] ->
representation_item =>
measure_representation_item <=
measure_with_unit =>
length_measure_with_unit
```

5.6 PLACE_TACK_OPERATION

```
AIM element: filling_type_operation
Source:        10303-238
Reference path:
filling_type_operation <=
machining_operation <=
action_method
{ action_method.description = 'place tack' }
```

5.7 PLACE_WASHER_OPERATION

```
AIM element: filling_type_operation
Source:        10303-238
Reference path:
filling_type_operation <=
machining_operation <=
action_method
{ action_method.description = 'place washer' }
```

5.8 PLACE_COLLAR_OPERATION

```
AIM element: filling_type_operation
Source:        10303-238
Reference path:
filling_type_operation <=
machining_operation <=
action_method
{ action_method.description = 'place collar' }
```

5.9 REMOVE_TACK_OPERATION

```
AIM element: filling_type_operation
Source:        10303-238
```

```
Reference path:
filling_type_operation <=
machining_operation <=
action_method
{ action_method.description = 'remove tack' }
```

5.10 SEAL_FASTENER_OPERATION

```
AIM element: filling_type_operation
Source:        10303-238
Reference path:
filling_type_operation <=
machining_operation <=
action_method
{ action_method.description = 'seal fastener' }
```

5.10.1 quantity

```
AIM element: measure_with_unit
Source:     10303-41
Reference path:
filling_type_operation <=
machining_operation <=
action_method
characterized_action_definition = action_method
characterized_action_definition <-
action_property.definition
{ action_property.name = 'quantity' }
action_property <-
action_property_representation.property
action_property_representation
action_property_representation.representation ->
representation
representation.items[i] ->
representation_item =>
measure_representation_item <=
measure_with_unit
{ measure_with_unit.value_component ->
measure_value measure_value = volume_measure
volume_measure }
```

5.10.2 seal_product_operation to material (as sealant)

```
AIM element: PATH
Reference path:
filling_type_operation <=
machining_operation <=
action_method <-
action_method_assignment.assigned_action_method
{ action_method_assignment.role ->
action_method_role
```

```
action_method_role.name = 'sealant' }
action_method_assignment =>
applied_action_method_assignment
applied_action_method_assignment.items[i] ->
action_method_items
action_method_items = product_definition
product_definition
characterized_definition = product_definition
characterized_definition <-
material_designation.definitions[i]
material_designation
```

5.11 SHAVE_FASTENER_OPERATION

```
AIM element: filling_type_operation
Source:        10303-238
Reference path:
filling_type_operation <=
machining_operation <=
action_method
{ action_method.description = 'shave fastener' }
```

5.11.1 reduction

```
AIM element: length_measure_with_unit
Source:    10303-41
Reference path:
filling_type_operation <=
machining_operation <=
action_method
characterized_action_definition = action_method
characterized_action_definition <-
action_property.definition
{ action_property.name = 'reduction' }
action_property <-
action_property_representation.property
action_property_representation
action_property_representation.representation ->
representation
representation.items[i] ->
representation_item =>
measure_representation_item <=
measure_with_unit =>
length_measure_with_unit
```

5.11.2 new_length

```
AIM element: length_measure_with_unit
Source:    10303-41
Reference path:
filling_type_operation <=
```

```
machining_operation <=
action_method
characterized_action_definition = action_method
characterized_action_definition <-
action_property.definition
{ action_property.name = 'new length' }
action_property <-
action_property_representation.property
action_property_representation
action_property_representation.representation ->
representation
representation.items[i] ->
representation_item =>
measure_representation_item <=
measure_with_unit =>
length_measure_with_unit
```

5.12 TIGHTEN_COLLAR_OPERATION

```
AIM element: filling_type_operation
Source:        10303-238
Reference path:
filling_type_operation <=
machining_operation <=
action_method
{ action_method.description = 'tighten collar' }
```

5.12.1 torque

```
AIM element: measure_with_unit
Source:    10303-41
Reference path:
filling_type_operation <=
machining_operation <=
action_method
characterized_action_definition = action_method
characterized_action_definition <-
action_property.definition
{ action_property.name = 'torque' }
action_property <-
action_property_representation.property
action_property_representation
action_property_representation.representation ->
representation
representation.items[i] ->
representation_item =>
measure_representation_item <=
measure_with_unit
{ measure_with_unit.value_component ->
measure_value
measure_value = numeric_measure
numeric_measure }
```

5.13 ADJUST_PLACEMENT_PROBING

```
AIM element: machining_touch_probing
Source:     10303-238
Reference path:
machining_touch_probing <=
machining_operation <=
action_method
{ action_method.description = 'adjust placement probing' }
NOTE: adjust mapping for feature complete probing to allow this string
```

5.13.1 adjusted_item

#1: if value is a product_definition

#2: if value is a machining_product_executable

```
AIM element: PATH
Reference path:
machining_touch_probing <=
machining_operation <=
action_method <-
action_method_assignment.assigned_action_method
{ action_method_assignment.role ->
action_method_role
action_method_role.name = 'adjusted item' }
action_method_assignment =>
applied_action_method_assignment
applied_action_method_assignment.items[i] ->
action_method_items
#1: (action_method_items = product_definition
product_definition)
#2: (action_method_items = action_method
action_method =>
machining_process_executable)
```

5.14 CONNECT_ESCAPE_STACK

```
AIM element: machining_toolpath
Source:     10303-238
Reference path:
machining_toolpath <=
action_method
{ action_method.description = 'connect escape' }
```

5.14.1 description

```
AIM element: descriptive_representation_item.description
Source:     10303-45
Reference path:
```

```
machining_toolpath <=
action_method
characterized_action_definition = action_method
characterized_action_definition <-
action_property.definition
{ action_property.name = 'description' }
action_property <-
action_property_representation.property
action_property_representation
action_property_representation.representation ->
representation representation.items[i] ->
representation_item =>
descriptive_representation_item
descriptive_representation_item.description
```

5.14.2 escape_point

```
AIM element: cartesian_point
Source:       10303-42
Reference path:
machining_toolpath <=
action_method
characterized_action_definition = action_method
characterized_action_definition <-
action_property.definition
{ action_property.name = 'escape point' }
action_property <-
action_property_representation.property
action_property_representation
action_property_representation.representation ->
representation
representation.items[i] ->
representation_item =>
geometric_representation_item =>
point =>
cartesian_point
```

5.14.3 pose_constraints

```
AIM element: value_range
Source:       10303-1106
Reference path:
machining_toolpath <=
action_method
characterized_action_definition = action_method
characterized_action_definition <-
action_property.definition
{ action_property.name = 'axis constraint' }
action_property <-
action_property_representation.property
action_property_representation
action_property_representation.representation ->
representation
```

```
representation.items[i] ->
representation_item =>
compound_representation_item =>
value_range
```

5.14.4 connect_escape_point to connect_escape_point (as next_level)

```
AIM element: PATH
Reference path:
machining_toolpath <=
action_method <-
action_method_relationship.relating_method
action_method_relationship
{ action_method_relationship.name = 'next level' }
action_method_relationship.related_method ->
action_method =>
machining_toolpath
```

5.15 CONNECT_ENTRY_STACK

```
AIM element: machining_toolpath
Source:      10303-238
Reference path:
machining_toolpath <=
action_method
{ action_method.description = 'connect entry' }
```

5.15.1 description

```
AIM element: descriptive_representation_item.description
Source:      10303-45
Reference path:
machining_toolpath <=
action_method
characterized_action_definition = action_method
characterized_action_definition <-
action_property.definition
{ action_property.name = 'description' }
action_property <-
action_property_representation.property
action_property_representation
action_property_representation.representation ->
representation representation.items[i] ->
representation_item =>
descriptive_representation_item
descriptive_representation_item.description
```

5.15.2 escape_point

```
AIM element: cartesian_point
```

```
Source:       10303-42
Reference path:
machining_toolpath <=
action_method
characterized_action_definition = action_method
characterized_action_definition <-
action_property.definition
{ action_property.name = 'escape point' }
action_property <-
action_property_representation.property
action_property_representation
action_property_representation.representation ->
representation
representation.items[i] ->
representation_item =>
geometric_representation_item =>
point =>
cartesian_point
```

5.15.3 pose_constraints

```
AIM element: value_range
Source:       10303-1106
Reference path:
machining_toolpath <=
action_method
characterized_action_definition = action_method
characterized_action_definition <-
action_property.definition
{ action_property.name = 'axis constraint' }
action_property <-
action_property_representation.property
action_property_representation
action_property_representation.representation ->
representation
representation.items[i] ->
representation_item =>
compound_representation_item =>
value_range
```

5.15.4 connect_entry_point to connect_entry_point (as next_level)

```
AIM element: PATH
Reference path:
machining_toolpath <=
action_method <-
action_method_relationship.relating_method
action_method_relationship
{ action_method_relationship.name = 'next level' }
action_method_relationship.related_method ->
action_method =>
machining_toolpath
```

5.16 EXTERNAL_OPERATION

```
AIM element: external_type_operation
Source:       10303-238
Reference path:
external_type_operation <=
machining_operation <=
action_method
```

5.16.1 mode

```
AIM element: descriptive_representation_item.description
Source:    10303-45
Reference path:
filling_type_operation <=
machining_operation <=
action_method
characterized_action_definition = action_method
characterized_action_definition <-
action_property.definition
{ action_property.name = 'mode' }
action_property <-
action_property_representation.property
action_property_representation
action_property_representation.representation ->
representation representation.items[i] ->
representation_item =>
descriptive_representation_item
descriptive_representation_item.description
{ (descriptive_representation_item.description = 'manual' )
(descriptive_representation_item.description = 'automated' ) }
```

5.16.2 additional_information

```
AIM element: descriptive_representation_item.description
Source:    10303-45
Reference path:
filling_type_operation <=
machining_operation <=
action_method
characterized_action_definition = action_method
characterized_action_definition <-
action_property.definition
{ action_property.name = 'additional information' }
action_property <-
action_property_representation.property
action_property_representation
action_property_representation.representation ->
representation representation.items[i] ->
representation_item =>
descriptive_representation_item
descriptive_representation_item.description
```

5.17 EXTERNAL_HEATING_OPERATION

```
AIM element: external_type_operation
Source:       10303-238
Reference path:
external_type_operation <=
machining_operation <=
action_method
{ action_method.description = 'heating' }
```

5.18 EXTERNAL_MARKING_OPERATION

```
AIM element: external_type_operation
Source:       10303-238
Reference path:
external_type_operation <=
machining_operation <=
action_method
{ action_method.description = 'marking' }
```

5.19 EXTERNAL_COATING_OPERATION

```
AIM element: external_type_operation
Source:       10303-238
Reference path:
external_type_operation <=
machining_operation <=
action_method
{ action_method.description = 'coating' }
```

5.20 EXTERNAL_PACKAGING_OPERATION

```
AIM element: external_type_operation
Source:       10303-238
Reference path:
external_type_operation <=
machining_operation <=
action_method
{ action_method.description = 'packaging' }
```

5.21 EXTERNAL_FASTENING_OPERATION

```
AIM element: external_type_operation
Source:       10303-238
Reference path:
external_type_operation <=
machining_operation <=
action_method
```

```
{ action_method.description = 'fastening' }
```

5.22 EXTERNAL_FIXTURING_OPERATION

```
AIM element: external_type_operation
Source:       10303-238
Reference path:
external_type_operation <=
machining_operation <=
action_method
{ action_method.description = 'fixturing' }
```

5.23 EXTERNAL_PREPARATION_OPERATION

```
AIM element: external_type_operation
Source:       10303-238
Reference path:
external_type_operation <=
machining_operation <=
action_method
{ action_method.description = 'preparation' }
```

5.24 EXTERNAL_REMOVAL_OPERATION

```
AIM element: external_type_operation
Source:       10303-238
Reference path:
external_type_operation <=
machining_operation <=
action_method
{ action_method.description = 'removal' }
```

6   AIM EXPRESS Additions

6.1   external_type_operation

An **external_type_operation** is a type of **machining_operation** that represents the details of an operation performed by an external system that is beyond the scope of the automation defined in this document. See the ARM definitions for External_operation and subtypes for more information.

6.1.1   EXPRESS specification:

*)

```
ENTITY external_type_operation
  SUBTYPE OF (machining_operation);
END_ENTITY;
(*
```

6.2 filling_type_operation

A **filling_type_operation** is a type of **machining_operation** that represents the details of a
machining step in which an existing hole or void is filled with a fastener. See the ARM
definitions for Filling_type_operation and subtypes for more information.

6.2.1 EXPRESS specification:

```
*)
ENTITY filling_type_operation
  SUBTYPE OF (machining_operation);
END_ENTITY;
(*
```

6.3 filling_type_group

A **filling_type_group** is a type of **machining_group** that collects manufacturing features within
a process where holes are drilled and filled. See the ARM definitions for Drill_and_fill_group
and subtypes for more information.

6.3.1 EXPRESS specification:

```
*)
ENTITY filling_type_group
  SUBTYPE OF (machining_group);
END_ENTITY;
(*
```

6.4 machining_group

A **machining_group** is a type of **group** and **characterized_object** that collects elements of a
manufacturing description.

6.4.1 EXPRESS specification:

```
*)
ENTITY machining_group
  SUBTYPE OF (group, characterized_object);
END_ENTITY;
(*
```

6.5 machining_stack

A **machining_stack** is a type of **action_method** that represents the ordering of elements in a drilling operation.

6.5.1 EXPRESS specification:

```
*)
ENTITY machining_stack
  SUBTYPE OF (action_method);
END_ENTITY;
(*
```

6.6 machining_stack_element

A **machining_stack_element** is a type of **action_method** that represents one element in a drilling operation.

6.6.1 EXPRESS specification:

```
*)
ENTITY machining_stack_element
  SUBTYPE OF (action_method);
END_ENTITY;
(*
```

6.7 mbmfg_date_and_time_item

EXTEND FROM AP238E3 DEFINITION

The **mbmfg_date_and_time_item** type is an extension of the **date_and_time_item** type. It adds the data types **characterized_object**, **machining_operation**, **machining_process_executable**, **machining_toolpath**, **product**, **product_definition**, and **product_definition_formation** to which a referenced **date_and_time** can be assigned.

6.7.1 EXPRESS specification:

```
*)
TYPE mbmfg_date_and_time_item = SELECT BASED_ON date_and_time_item WITH (
  characterized_object,    -- ADD
  machining_group,
  machining_operation,
```

```
    machining_process_executable,
    machining_toolpath,
    product,
    product_definition,
    product_definition_formation
    );
END_TYPE;
(*
```

6.8 twin_feature

A **twin_feature** is a type of **instanced_feature** that represents the as-made result of a
manufacturing operation on a digital twin. See the ARM definitions for
Manufacturing_feature_twin and subtypes for more information.

6.8.1 EXPRESS specification:

```
*)
ENTITY twin_feature
  SUBTYPE OF (instanced_feature);
END_ENTITY;
(*
```

6.9 twin_prototype_relationship

A **twin_prototype_relationship** is a type of **property_definition_relationship** that associates
the digital twin description of an as-made concept with its as-designed description. See the ARM
definitions for Product_view_twin, Geometric_tolerance_twin, Dimensional_size_twin, and
Dimensional_location_twin for more information.

6.9.1 EXPRESS specification:

```
*)
ENTITY twin_prototype_relationship
  SUBTYPE OF (property_definition_relationship);
END_ENTITY;
(*
```

6.10 twin_substitute_relationship

A **twin_substitute_relationship** is a type of **property_definition_relationship** that associates
the digital twin description of an as-made concept with a substitute description. See the ARM
definitions for Product_view_twin_with_substitute for more information.

6.10.1 EXPRESS specification:

```
*)
ENTITY twin_substitute_relationship
  SUBTYPE OF (property_definition_relationship);
END_ENTITY;
(*
```

7 Change Log

2023-09-01 – updating to new drill/fill twin feature, group model, more specific operations, plus mappings.

2023-04-11 – updating to version M.   In progress.

2023-04-07 – updated to version L. Removed fasten_operation, identify_operation, serialize_operation, and load_nose.